User's Manual

CubeSuite+ V2.01.00

Integrated Development Environment
User's Manual: RH850 Coding

Target Device
RH850 Family

Renesas Electronics
www.renesas.com

Rev.1.01 Sep 2013

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
3. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from such alteration, modification, copy or otherwise misappropriation of Renesas Electronics product.
5. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality”. The recommended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.

   “Standard”: Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots etc.

   “High Quality”: Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; and safety equipment etc.

   Renesas Electronics products are neither intended nor authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems, surgical implantations etc.), or may cause serious property damages (nuclear reactor control systems, military equipment etc.). You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application for which it is not intended. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for which the product is not intended by Renesas Electronics.
6. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You should not use Renesas Electronics products or technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. When exporting the Renesas Electronics products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, who distributes, disposes of, or otherwise places the product with a third party, to notify such third party in advance of the contents and conditions set forth in this document, Renesas Electronics assumes no responsibility for any losses incurred by you or third parties as a result of unauthorized use of Renesas Electronics products.
11. This document may not be reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.

(Note 1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.

(Note 2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.

(2012.4)

How to Use This Manual

This manual describes the role of the CubeSuite+ integrated development environment for developing applications and systems for RH850 family, and provides an outline of its features.

CubeSuite+ is an integrated development environment (IDE) for RH850 family, integrating the necessary tools for the development phase of software (e.g. design, implementation, and debugging) into a single platform.

By providing an integrated environment, it is possible to perform all development using just this product, without the need to use many different tools separately.

Readers

This manual is intended for users who wish to understand the functions of the CubeSuite+ and design software and hardware application systems.

Purpose

This manual is intended to give users an understanding of the functions of the CubeSuite+ to use for reference in developing the hardware or software of systems using these devices.

Organization

This manual can be broadly divided into the following units.

CHAPTER 1 GENERAL
CHAPTER 2 FUNCTIONS
CHAPTER 3 COMPILER LANGUAGE SPECIFICATIONS
CHAPTER 4 ASSEMBLY LANGUAGE SPECIFICATIONS
CHAPTER 5 SECTION ALLOCATION
CHAPTER 6 FUNCTIONAL SPECIFICATIONS
CHAPTER 7 STARTUP
CHAPTER 8 REFERENCING COMPILER AND ASSEMBLER
CHAPTER 9 CAUTIONS
APPENDIX A WINDOW REFERENCE
APPENDIX B INDEX

How to Read This Manual

It is assumed that the readers of this manual have general knowledge of electricity, logic circuits, and microcontrollers.

Conventions

Data significance:	Higher digits on the left and lower digits on the right
Active low representation:	$\overline{\text{XXX}}$ (overscore over pin or signal name)
Note:	Footnote for item marked with Note in the text
Caution:	Information requiring particular attention
Remark:	Supplementary information
Numeric representation:	Decimal ... XXXX
	Hexadecimal ... 0xXXXX

Related Documents

The related documents indicated in this publication may include preliminary versions. However, preliminary versions are not marked as such.

Document Name		Document No.
CubeSuite+ Integrated Development Environment User's Manual	Start	R20UT2682E
	RX Design	R20UT2683E
	V850 Design	R20UT2134E
	R8C Design	R20UT2135E
	RL78 Design	R20UT2684E
	78K0R Design	R20UT2137E
	78K0 Design	R20UT2138E
	RH850 Coding	This manual
	RX Coding	R20UT2470E
	V850 Coding	R20UT0553E
	Coding for CX Compiler	R20UT2659E
	R8C Coding	R20UT0576E
	RL78,78K0R Coding	R20UT2140E
	78K0 Coding	R20UT2141E
	RH850 Build	R20UT2585E
	RX Build	R20UT2472E
	V850 Build	R20UT0557E
	Build for CX Compiler	R20UT2142E
	R8C Build	R20UT0575E
	RL78,78K0R Build	R20UT2143E
	78K0 Build	R20UT0783E
	RH850 Debug	R20UT2685E
	RX Debug	R20UT2702E
	V850 Debug	R20UT2446E
	R8C Debug	R20UT0770E
	RL78 Debug	R20UT2445E
	78K0R Debug	R20UT0732E
	78K0 Debug	R20UT0731E
	Analysis	R20UT2686E
	Message	R20UT2687E

Caution The related documents listed above are subject to change without notice. Be sure to use the latest edition of each document when designing.

TABLE OF CONTENTS

CHAPTER 1 GENERAL ... 9

1.1 Outline ... 9
1.2 Special Features ... 9
1.3 Limits ... 9

CHAPTER 2 FUNCTIONS ... 11

2.1 Variables (C Language) ... 11
2.1.1 Allocating to sections accessible with short instructions ... 11
2.1.2 Changing allocated section ... 13
2.1.3 Change the allocated area using the -Xpreinclude option ... 15
2.1.4 Defining variables for use during standard and interrupt processing ... 16
2.1.5 Defining const constant pointer ... 18
2.2 Functions ... 19
2.2.1 Changing area to be allocated to ... 19
2.2.2 Calling away function ... 19
2.2.3 Embedding assembler instructions ... 20
2.2.4 Executing in RAM ... 20
2.3 Variables (Assembler) ... 21
2.3.1 Defining variables with no initial values ... 21
2.3.2 Defining variable with initial values ... 22
2.3.3 Defining const constants ... 23

CHAPTER 3 COMPILER LANGUAGE SPECIFICATIONS ... 24

3.1 Basic Language Specifications ... 24
3.1.1 Unspecified behavior ... 24
3.1.2 Undefined behavior ... 25
3.1.3 Processing system dependent items ... 27
3.1.4 C99 language function ... 37
3.1.5 Option to process in strict accordance with ANSI standard ... 39
3.1.6 Internal representation and value area of data ... 40
3.1.7 Section name ... 48
3.1.8 Register mode ... 49
3.2 Extended Language Specifications ... 51
3.2.1 Macro name ... 51
3.2.2 Reserved words ... 52
3.2.3 Compiler generated symbols ... 52
3.2.4 #pragma directive ... 52
3.2.5 Using extended language specifications ... 54
3.2.6 Modification of C source ... 94

CHAPTER 4 ASSEMBLY LANGUAGE SPECIFICATIONS ... 95

4.1 Description of Source ... 95
4.1.1 Description ... 95
4.1.2 Expressions and operators ... 104
4.1.3 Arithmetic operators ... 106
4.1.4 Logic operators ... 114
4.1.5 Relational operators ... 119
4.1.6 Shift operators ... 128
4.1.7 Byte separation operators ... 131
4.1.8 2-byte separation operators ... 134
4.1.9 Section aggregation operators ... 138
4.1.10 Other operator ... 143
4.1.11 Restrictions on operations ... 145
4.1.12 Identifiers ... 146
4.2 Directives ... 147
4.2.1 Outline ... 147
4.2.2 Section definition directives ... 148
4.2.3 Symbol definition directives ... 158
4.2.4 Compiler output directives ... 161
4.2.5 Data definition/Area reservation directives ... 167
4.2.6 External definition/External reference directives ... 181
4.2.7 Macro directives ... 185
4.3 Control Instructions ... 197
4.3.1 Outline ... 197
4.3.2 Assembler control instructions ... 198
4.3.3 File input control instructions ... 206
4.3.4 Conditional assembly control instructions ... 209
4.4 Macro ... 218
4.4.1 Outline ... 218
4.4.2 Usage of macro ... 218
4.4.3 Macro operator ... 219
4.5 Reserved Words ... 220
4.6 Assembler Generated Symbols ... 221
4.7 Instruction Set ... 222
4.8 Description of Instructions ... 234
4.8.1 Load/Store instructions ... 235
4.8.2 Arithmetic operation instructions ... 247
4.8.3 Saturated operation instructions ... 301
4.8.4 Logical instructions ... 311
4.8.5 Branch instructions ... 346
4.8.6 Bit manipulation instructions ... 366
4.8.7 Stack manipulation instructions ... 375
4.8.8 Special instructions ... 380
4.8.9 Loop instructions ... 416
4.8.10 Floating-point operation instructions ... 419
4.8.11 Other instructions ... 499

CHAPTER 5 SECTION ALLOCATION ... 500

5.1 Sections ... 500
5.1.1 Section concatenation ... 500
5.2 Special Symbol ... 502

CHAPTER 6 FUNCTIONAL SPECIFICATIONS ... 504

6.1 Supplied Libraries ... 504
6.2 Header Files ... 504
6.3 Re-entrant ... 505
6.4 Library Function ... 506
6.4.1 Program diagnostic functions ... 506
6.4.2 Functions with variable arguments ... 508
6.4.3 Character string functions ... 512
6.4.4 Memory management functions ... 528
6.4.5 Character conversion functions ... 534
6.4.6 Character classification functions ... 537
6.4.7 Standard I/O functions ... 550
6.4.8 Standard utility functions ... 584
6.4.9 Non-local jump functions ... 613
6.4.10 Mathematical functions ... 617
6.4.11 RAM section initialization function ... 663
6.4.12 Initialization peripheral devices function ... 666
6.4.13 Operation runtime functions ... 668

CHAPTER 7 STARTUP ... 670

7.1 Outline ... 670
7.2 Startup Routine ... 670
7.2.1 Exception vector table ... 670
7.2.2 Startup routine for the boot loader project ... 671
7.2.3 Startup routine for the application project ... 674
7.2.4 Passing information from the application project to the boot loader project ... 679
7.3 Coding Example ... 680
7.4 Symbols ... 691
7.4.1 Global pointer (gp) ... 692
7.4.2 Element pointer (ep) ... 694
7.5 ROMization ... 698
7.5.1 Outline ... 698
7.5.2 Creating ROMized load module file ... 699

CHAPTER 8 REFERENCING COMPILER AND ASSEMBLER ... 701

8.1 Function Call Interface ... 701
8.1.1 General-purpose registers guaranteed before and after function calls ... 701
8.1.2 Setting and referencing arguments and return values ... 701
8.1.3 Address indicating stack pointer ... 704
8.1.4 Stack frame ... 704
8.2 Calling of Assembly Language Routine from C Language ... 707
8.3 Calling of C Language Routine from Assembly Language ... 708

8.4 Reference of Argument Defined by Other Language ... 709
8.5 General-purpose Registers ... 709

CHAPTER 9 CAUTIONS ... 711

9.1 Volatile Qualifier ... 711
9.2 V850E3v5 G3K Core Specification for Assembler (-Xcpu=g3k Option) ... 712

APPENDIX A WINDOW REFERENCE ... 713

A.1 Description ... 713

APPENDIX B INDEX ... 739

CHAPTER 1 GENERAL

This chapter provides a general outline of the RH850 family's C compiler package (CC-RH).

1.1 Outline

CC-RH is a program that converts programs described in C language or assembly language into machine language.

1.2 Special Features

CC-RH is equipped with the following special features.

(1) Language specifications in accordance with ANSI standard

The C language specifications conform to the ANSI standard.

(2) Advanced optimization

Advanced optimization is used, applying global program optimization as well as conventional optimization. This yields smaller, faster code, and also reduces build times.

(3) High portability

The program supports porting programs from the existing SuperH RISC engine C/C++ compiler. In addition, the industry-standard DWARF2 format is used for debugging information.

(4) Multifunctional

Static analysis and other functionality is provided via linking between CubeSuite+.

1.3 Limits

The maximum values that can be coded in C and assembly-language programs are indicated below.

(1) Compiler limits

There are no limits on translation. The maximum translatable value depends on the memory of the host machine on which the program is running. Exceeding the maximum value an assembler specified will result in an error.

Remark The maximum number of bytes for one object is 2 Gbytes (in the host environment).

(2) Assembler limits

The maximum values that can be coded in assembly-language programs are indicated below.

Table 1-1. Assembler Limits

Description	Limit
Symbol length (Token length)	4,294,967,294Note
Label length (Token length)	4,294,967,294Note
Number of symbols	4,294,967,294Note
Number of parameters in LOCAL directive	4,294,967,294Note
Number of automatically generated LOCAL directive symbols	4,294,967,294Note
Nesting levels in INCLUDE directive	4,294,967,294 Note
TDATA relocation attribute section	256 bytes

Description	Limit
ALIGN directive	Even number of 2 or more, but less than 2^{31}
Number of arguments in IRP directive	4,294,967,294[Note]

Note Depends on memory of host machine on which it is running.

CHAPTER 2 FUNCTIONS

This chapter explains the programming method and how to use the expansion functions for more efficient use of the CC-RH.

2.1 Variables (C Language)

This section explains variables (C language).

2.1.1 Allocating to sections accessible with short instructions

CC-RH normally uses two instructions (for a total of 8 bytes) to access variables: a movhi instruction (4 bytes) and an ld/st instruction (4 bytes). By using a #pragma section directive, however, it generates code to access variables using one instruction: an ld/st instruction (4 or 6 bytes) or a sld/sst instruction (2 bytes). This makes it possible to reduce the code size. See below for details.

(1) GP relative access

This generates code to access variables using one instruction by placing variables in sections that can be accessed via the global pointer (GP) and an ld/st instruction.

Use a #pragma section directive when defining or accessing variables, and specify either gp_disp16 or gp_disp23 as the attribute strings.

```
#pragma section attribute-strings
variable-declaration/definition
#pragma section default
```

Examples 1. Accessing via a GP-relative 4-byte load/store instruction

```
#pragma section gp_disp16
int a = 1;              /*allocated to .sdata section*/
int b;                  /*allocated to .sbss section*/
#pragma section default
```

2. Accessing via a GP-relative 6-byte load/store instruction

```
#pragma section gp_disp23
int a = 1;             /*allocated to .sdata23 section*/
int b;                 /*allocated to .sbss23 section*/
#pragma section default
```

(2) EP relative access

You can reduce the code size by locating variables in a section that can be accessed via the element pointer (EP) and a sld/sst instruction or ld/st instruction. You can locate variables in a section that can be accessed relative to the EP using the following methods.

(a) Specifying the -Omap/-Osmap option

This optimizes access to external variables. It outputs code that accesses frequently accessed external variables relative to the EP.

(b) #pragma section directive

Use a #pragma section directive when defining or accessing variables, and specify either ep_disp4, ep_disp5, ep_disp7, ep_disp8, ep_disp16, ep_disp23, or ep_auto as the attribute string.

```
#pragma section attribute-strings
variable-declaration/definition
#pragma section default
```

Examples 1. Accessing via a EP-relative 2-byte load/store instruction

```
#pragma section ep_disp4
int a = 1;              /*allocated to .tdata4 section*/
int b;                  /*allocated to .tbss4 section*/
#pragma section default
```

Even if ep_disp5, ep_disp7, or ep_disp8 is specified as the attribute string, access is via an EP-relative 2-byte load/store instruction (i.e. is the same as in the case of ep_disp4).

2. Accessing via a EP-relative 4-byte load/store instruction

```
#pragma section ep_disp16
int a = 1;              /*allocated to .edata section*/
int b;                  /*allocated to .ebss section*/
#pragma section default
```

3. Accessing via a EP-relative 6-byte load/store instruction

```
#pragma section ep_disp23
int a = 1;              /*allocated to .edata23 section*/
int b;                  /*allocated to .ebss23 section*/
#pragma section default
```

2.1.2 Changing allocated section

The default allocation sections are as follows:

- Variables with no initial value: .bss section
- Variables with initial value: .data section
- const constants: .const section

To change the allocated section, specify the attribute strings using #pragma section directive.

The relationship between attribute strings and the section generated is as follows.

Attribute Strings	Initial Value	Default Section Name	Section Name Change	Base Register	Access Instruction
r0_disp16	Yes	.zdata	Possible	r0	ld/st 1 instruction
	No	.zbss	Possible	r0	ld/st 1 instruction
r0_disp23	Yes	.zdata23	Possible	r0	ld23/st23 1 instruction
	No	.zbss23	Possible	r0	ld23/st23 1 instruction
r0_disp32	Yes	.data	Possible	r0	movhi+ld/st 2 instruction
	No	.bss	Possible	r0	movhi+ld/st 2 instruction
ep_auto	Yes/No	Automatically selected from among .tdata4, .tdata5, .tdata7, and .tdata8	Impossible	ep	sld/sst 1 instruction
ep_disp4	Yes	.tdata4	Possible	ep	sld/sst 1 instruction
	No	.tbss4	Possible	ep	sld/sst 1 instruction
ep_disp5	Yes	.tdata5	Possible	ep	sld/sst 1 instruction
	No	.tbss5	Possible	ep	sld/sst 1 instruction
ep_disp7	Yes	.tdata7	Possible	ep	sld/sst 1 instruction
	No	.tbss7	Possible	ep	sld/sst 1 instruction
ep_disp8	Yes	.tdata8	Possible	ep	sld/sst 1 instruction
	No	.tbss8	Possible	ep	sld/sst 1 instruction
ep_disp16	Yes	.edata	Possible	ep	ld/st 1 instruction
	No	.ebss	Possible	ep	ld/st 1 instruction
ep_disp23	Yes	.edata23	Possible	ep	ld23/st23 1 instruction
	No	.ebss23	Possible	ep	ld23/st23 1 instruction
gp_disp16	Yes	.sdata	Possible	gp	ld/st 1 instruction
	No	.sbss	Possible	gp	ld/st 1 instruction
gp_disp23	Yes	.sdata23	Possible	gp	ld23/st23 1 instruction
	No	.sbss23	Possible	gp	ld23/st23 1 instruction
const	Yes	.const	Possible	r0	movhi+ld/st 2 instruction
zconst	Yes	.zconst	Possible	r0	ld/st 1 instruction
zconst23	Yes	.zconst23	Possible	r0	ld23/st23 1 instruction
default	After this statement, any previous #pragma section will be ignored, and the default allocation will be used.				

Example #pragma section directive description

```
#pragma section gp_disp16 "mysdata"
int a = 1;              /*allocated to mysdata.sdata attribute section*/
int b;                  /*allocated to mysdata.sbss attribute section*/
#pragma section default
```

When referencing a variable using the #pragma section directive from a function in another file (i.e. reference file), it is necessary to also specify the #pragma section directive in the reference file and to define the affected variable as extern format.

Unlike when specifying a variable by means of a definition or declaration, it outputs the following error if the variable cannot be accessed with the specified section attribute.

```
E0562330 : Relocation size overflow : "file"-"section"-"offset"
```

Examples 1. File that defines a table

```
#pragma section zconst
const unsigned char table_data[9] = {1, 2, 3, 4, 5, 6, 7, 8, 9}; /*allocated to .zconst
section*/
#pragma section default
```

2. File that references a table

```
#pragma section zconst
extern  const unsigned char  table_data[];      /*allocated to .zconst section*/
#pragma section default
```

Code such as the following can be used if portability of C source to the SH family of compilers is a concern.

Example #pragma section directive description

```
#pragma section mydata
int a = 1;              /*allocated to mydata.data section*/
int b;                  /*allocated to mydata.bss section*/
#pragma section default
```

2.1.3 Change the allocated area using the -Xpreinclude option

You can use the -Xpreinclude option to allocate all variables declared or defined in a file into an arbitrary section, without changing the C source file. You can reduce the code size by allocating them in a section with efficient access.

(1) Prepare a header file (.h) containing a #pragma section directive.

Example Allocating in .sdata/.sbss section [section.h]

```
#pragma section gp_disp16
```

(2) Use the -Xpreinclude option to include the header you created in (1) at the beginning of the compilation unit.

Example If the header file with the specified section is section.h

```
>ccrh main.c -Xpreinclude=section.h
```

Compiled as if main.c starts with an include of "section.h".

However, a link-time error will be output if the variables do not fit in the section specified in (1). In this case, change the section of the variables in the C source file.

```
E0562330 : Relocation size overflow : "file"-"section"-"offset"
```

Example Changing variables to .sdata23/.sbss23 section

```
int a = 1;              /*Allocated in section specified in (1)*/
int b;                  /*Allocated in section specified in (1)*/
#pragma section gp_disp23
int c = 1;              /*Allocated in .sdata23 section*/
int d;                  /*Allocated in .sbss23 section*/
#pragma section default
int e = 1;              /*Allocated in default .data section*/
int f;                  /*Allocated in default .bss section*/
```

2.1.4 Defining variables for use during standard and interrupt processing

Specify as volatile variables that are to be used during both standard and interrupt processing.

When a variable is defined with the volatile qualifier, the variable is not optimized. When manipulating variables specified as volatile, always read the value from memory, and when substituting the value, always write the value to memory. You cannot change the access order or access width of variables specified as volatile. A variable for which volatile is not specified is assigned to a register as a result of optimization and the code that loads the variable from the memory may be deleted. When the same value is assigned to variables for which volatile is not specified, the instruction may be deleted as a result of optimization because it is interpreted as a redundant instruction.

Examples 1. Example of source and output code image when volatile is not specified

If variables a and b are not specified with the volatile quantifier, they are assigned to a register, and may be optimized. If, for example, an interrupt occurs within this code, and a variable value is modified within the interrupt, the value will not be reflected.

```
int a;
int b;
void func(void){
    if(a <= 0){
        b++;
    } else {
        b+=2;
    }
    b++;
}
```

```
_func:
        movhi   highw1(#_a), r0, r6
        ld.w    loww(#_a)[r6], r6
        cmp     0x00000000, r6
        movhi   highw1(#_b), r0, r6
        ld.w    loww(#_b)[r6], r6
        bgt     .bb1_2          ; bb3
.bb1_1:     ; bb1
        add     0x00000001, r6
        br      .bb1_3          ; bb9
.bb1_2:     ; bb3
        add     0x00000002, r6
.bb1_3:     ; bb9
        add     0x00000001, r6
        movhi   highw1(#_b), r0, r7
        st.w    r6, loww(#_b)[r7]
        jmp     [r31]
```

2. Source and output code when volatile has been specified

If the volatile qualifier is specified for variables a, b, and c, the output code is such that the values of these variables are read from and written to memory whenever they must be assigned new values. Even if an interrupt occurs in the meantime and the values of the variables are changed by the interrupt, for example, the result in which the change is reflected can be obtained.

When volatile is specified, the code size increases compared with when volatile is not specified because the memory has to be read and written.

```
volatile int a;
volatile int b;
void func(void){
    if(a <= 0){
        b++;
    } else {
        b+=2;
    }
    b++;
}
```

```
_func:
        movhi   highw1(#_a), r0, r6
        ld.w    loww(#_a)[r6], r6
        cmp     0x00000000, r6
        bgt     .bb1_2          ; bb3
.bb1_1:    ; bb1
        movhi   highw1(#_b), r0, r6
        ld.w    loww(#_b)[r6], r6
        add     0x00000001, r6
        br      .bb1_3          ; bb9
.bb1_2:    ; bb3
        movhi   highw1(#_b), r0, r6
        ld.w    loww(#_b)[r6], r6
        add     0x00000002, r6
.bb1_3:    ; bb9
        movhi   highw1(#_b), r0, r7
        st.w    r6, loww(#_b)[r7]
        ld.w    loww(#_b)[r7], r6
        add     0x00000001, r6
        st.w    r6, loww(#_b)[r7]
        jmp     [r31]
```

2.1.5 Defining const constant pointer

The pointer is interpreted differently depending on the "const" specified location.

To assign the const section to the zconst section, specify #pragma section zconst. To assign the const section to the zconst23 section, specify #pragma section zconst23.

- const char *p;

  This indicates that the object (*p) indicated by the pointer cannot be rewritten.

  The pointer itself (p) can be rewritten.

  Therefore the state becomes as follows and the pointer itself is allocated to RAM (.data etc.).

```
*p = 0;      /*error*/
p = 0;       /*correct*/
```

- char *const p;

  This indicates that the pointer itself (p) cannot be rewritten.

  The object (*p) indicated by the pointer can be rewritten.

  Therefore the state becomes as follows and the pointer itself is allocated to ROM (.const/.zconst/.zconst23).

```
*p = 0;      /*correct*/
p = 0;       /*error*/
```

- const char *const p;

  This indicates that neither the pointer itself(p) nor the object (*p) indicated by the pointer can be rewritten.

  Therefore the state becomes as follows and the pointer itself is allocated to ROM (.const/.zconst/.zconst23).

```
*p = 0;      /*error*/
p = 0;       /*error*/
```

2.2 Functions

This section explains functions.

2.2.1 Changing area to be allocated to

When changing a program area's section name, specify the function using the #pragma section directive as shown below.

```
#pragma section text  ["section name"]
```

If you create an arbitrary section with a text attribute using the #pragma section directive, the name of the section that is generated will be "specified-string + text".

Specify the start address of the section with the -start option, as follows.

```
-start=sec.text/1000
```

Specify the address as a base-16 number. If the address is not specified, it will be assigned from address 0.

The -start option is a link option. For details, see "CubeSuite+ Integrated Development Environment User's Manual: RH850 Build".

2.2.2 Calling away function

The C compiler uses the jarl instruction to call functions.

However, depending on the program allocation the address may not be able to be resolved, resulting in an error when linking because the jarl instruction is 22-bit displacement.

One way to resolve the error above is to first specify -Xcall_jump=32 to generate jarl32 and jr32 instructions.

If the -Xcall_jump=22 option is specified, then you can make function calls that do not depend on the displacement width by specifying the C compiler's -Xfar_jump option.

When calling a function set as far jump, the jarl32 and jr32 instruction rather than the jarl instruction is output.

One function is described per line in the file where the -Xfar_jump option is specified. The names described should be C language function names prefixed with "_" (an underscore).

Example The file where the -Xfar_jump option is specified

```
_func_led
_func_beep
_func_motor
    :
_func_switch
```

If the following is described in place of "_function-name", all functions will be called using far jump.

```
{all_function}
```

2.2.3 Embedding assembler instructions

With the CC-RH assembler instructions can be described in the following formats within C source programs. This treats the function itself as an assembler instruction, and performs inline expansion at the call site.

- #pragma directive

```
#pragma inline_asm
static int func(int a, int b) {
        /*Assembler instruction*/
}
```

Remarks 1. Note the following when using inline assembly.

- Specify #pragma inline_asm before the definition of the function body.
- Also generate external definitions of functions specified with #pragma inline_asm.
- If you use a register to guarantee the entrance and exit of an inline function with embedded assembly, you must save and restore this register at the beginning and end of the function.
- RH850 assembly language can use comments starting with the hash character ("#"). Do not use # comments inside functions coded in assembly, because the preprocessor will interpret these as preprocessing directives.
- If you write a label in a function coded in assembly, labels with the same name will be created for each inline expansion. In this situation, use local labels coded in assembly. Although local labels have the same name in the assembly source, the assembler converts them to different names automatically.

2. See "Describing assembler instruction".

2.2.4 Executing in RAM

A program allocated to external ROM can be copied to internal RAM and executed in internal RAM while linking and after copying if the relative value of each section and each symbol (TP, EP, GP) is not destroyed. Use caution, as some programs can be copied while others cannot.

After resetting, it is copied to internal RAM, and if the program is not changed, then the ROMization function can be used to easily pack the text section.

2.3 Variables (Assembler)

This section explains variables (Assembler).

2.3.1 Defining variables with no initial values

Use the .ds directive in a section with no initial value to allocate area for a variable with no initial value.

```
[label:]        .ds     (size)
```

In order that it may be referenced from other files as well, it is necessary to define the label with the .public directive.

```
.public label name[, absolute-expression]
```

Example Defining variables with no initial values

```
        .dseg   sdata
        .public _val0, 0x4      --Sets _val0 as able to be referenced from other files
        .public _val1, 0x2      --Sets _val1 as able to be referenced from other files
        .public _val2, 0x1      --Sets _val2 as able to be referenced from other files
        .align  4               --Aligns _val0 to 4 bytes
_val0:
        .ds     (4)             --Allocates 4 bytes of area for val0
_val1:
        .ds     (2)             --Allocates 2 bytes of area for val1
_val2:
        .ds     (1)             --Allocates 1 byte of area for val2
```

2.3.2 Defining variable with initial values

To allocate a variable area with a default value, use the .db directives/.db2/.dhw directives/.db4/.dw directives in the section with the default value.

- 1-byte values

```
[label:]        .db value
```

- 2-byte values

```
[label:]        .db2 value
```

- 4-byte values

```
[label:]        .db4 value
```

In order that it may be referenced from other files as well, it is necessary to define the label with the .public directive.

```
.public label name[, absolute-expression]
```

Example Defining variable with initial values

```
        .dseg   sbss
        .public _val0, 0x4      --Sets _val0 as able to be referenced from other files
        .public _val1, 0x2      --Sets _val1 as able to be referenced from other files
        .public _val2, 0x1      --Sets _val2 as able to be referenced from other files
        .align  4               --Aligns _val0 to 4 bytes
_val0:
        .db4    100             --Allocates a 4-byte area for _val0, and stores 100 in it
_val1:
        .db2    10              --Allocates a 2-byte area for _val0, and stores 10 in it
_val2:
        .db     1               --Allocates a 1-byte area for _val0, and stores 1 in it
```

2.3.3 Defining const constants

To define a const, use the .db directives/.db2/.dhw directives/.db4/.dw directives within the .const, .zconst or .zconst23 section.

- 1-byte values

```
[label:]        .db value
```

- 2-byte values

```
[label:]        .db2 value
```

- 4-byte values

```
[label:]        .db4 value
```

Example Defining const constants

```
        .cseg   const
        .public _p, 0x2         --Sets _p as able to be referenced from other files
        .align  4               --Aligns _val0 to 4 bytes
_p:
        .db2    10              --Allocates a 2-byte area for _p, and stores 10 in it
```

CHAPTER 3 COMPILER LANGUAGE SPECIFICATIONS

This chapter explains Compiler language specifications (basic language specification, extended language specifications, etc.)supported by the CC-RH.

3.1 Basic Language Specifications

The CC-RH supports the language specifications stipulated by the ANSI standards. These specifications include items that are stipulated as processing definitions. This section describes language specifications that are not specified or defined by the ANSI standard, or that are process-dependent.

It describes the differences between when the option for processing in strict compliance with the ANSI standard (-Xansi) is specified, and when it is not.

See "3.2 Extended Language Specifications" for extended language specifications explicitly added by the CC-RH.

3.1.1 Unspecified behavior

This section describes behavior that is not specified by the ANSI standard.

(1) Execution environment - initialization of static storage

Static data is output during compilation as a data section.

(2) Meanings of character displays - final line location, backspace (\b), horizontal tab (\t), vertical tab (\t)

This is dependent on the design of the display device.

(3) Types - floating point

IConforms to IEEE754[Note].

Note IEEE: Institute of Electrical and Electronics Engineers
IEEE754 is a system for handling floating-point calculations, providing a uniform standard for data formats, numerical ranges, and the like handled.

(4) Expressions - evaluation order

Unspecified.

(5) Function calls - parameter evaluation order

Unspecified.

(6) Structure and union specifiers

See "(8) Bit field" for the boundary alignment of structure objects with bit fields.

(7) Function definitions - storage of formal parameters

Unspecified.

(8) # operator

Unspecified.

3.1.2 Undefined behavior

This section describes behavior that is not defined by the ANSI standard.

(1) Character set

A message is output if a source file contains a character not specified by the character set.

(2) Lexical elements

A message is output if there is a single or double quotation mark ("/") in the last category (a delimiter or a single non-whitespace character that does not lexically match another preprocessing lexical type).

(3) Identifiers

Since all identifier characters have meaning, there are no meaningless characters.

(4) Identifier binding

A message is output if both internal and external binding was performed on the same identifier within a translation unit.

(5) Compatible type and composite type

All declarations referencing the same object or function must be compatible. Otherwise, a message will be output.

(6) Character constants

Specific non-graphical characters can be expressed by means of extended notation, consisting of a backslash (\) followed by a lower-case letter. The following are available: \a, \b, \f, \n, \r, \t, and \v. There is no other extended notation; other letters following a backslash (\) become that letter.

(7) String literals - concatenation

When a simple string literal is adjacent to a wide string literal token, they are concatenated into a wide string literal.

(8) String literals - modification

Users modify string literals at their own risk.

(9) Header names

If the following characters appear in strings between the delimiter characters < and >, or between two double quotation marks ("), then they are treated as part of the file name: characters, comma (,), double quote ("), two slashes (//), or slash-asterisk (/*). The backslash (\) is treated as a folder separator.

(10) Floating point type and integral type

If a floating-point type is typecast into an integral type, and the integer portion cannot be expressed as an integral type, then it is undefined.

(11) lvalues and function specifiers

If an incomplete type becomes an value, then it is undefined..

(12) Function calls - number of arguments

If there are not enough actual parameters, then it is undefined.

(13) Function calls - types of extended parameters

If a function is defined without a function prototype, and the types of the extended arguments do not match the types of the extended formal parameters, then the values of the formal parameters will be undefined.

(14) Function calls - incompatible types

If a function is defined with a type that is not compatible with the type specified by the expression indicating the called function, then the return value of the function will be invalid.

(15) Function calls - incompatible types

If a function is defined in a form that includes a function prototype, and the type of an extended argument is not compatible with that of a formal parameter, or if the function prototype ends with an ellipsis, then it will be interpreted as the type of the formal parameter.

(16) Addresses and indirection operators

If an incorrect value is assigned to a pointer, then the behavior of the unary * operator will either obtain an undefined value or result in an illegal access, depending on the hardware design and the contents of the incorrect value.

(17) Cast operator - function pointer casts

If a typecast pointer is used to call a function with other than the original type, then it is undefined.

(18) Cast operator - integral type casts

If a pointer is cast into an integral type, and the amount of storage is too small, then it is undefined.

(19) Multiplicative operators

A message will be output if a divide by zero is detected during compilation.

(20) Additive operators - non-array pointers

If addition or subtraction is performed on a pointer that does other than indicate elements in an array object, then it is undefined.

(21) Additive operators - subtracting a pointer from another array

If subtraction is performed using two pointers that do not indicate elements in the same array object, then it is undefined.

(22) Bitwise shift operators

If the right operand is negative or the expanded left operand is wider than the bit width, then it is undefined.

(23) Function operators - pointers

If the objects referred to by the pointers being compared are not members of the same aggregate or union object, then it is undefined.

(24) Simple assignment

If a value stored in an object is accessed via another object that overlaps that object's storage area in some way, then the overlapping portion must match exactly. Furthermore, the types of the two objects must have modified or non-modified versions with compatible types. Assignment to non-matching overlapping storage could cause the value of the assignment source to become corrupted.

(25) Structure and union specifiers

If the member declaration list does not include named members, then a message will be output warning that the list has no effect. Note, however, that the same message will be output accompanied by an error if the -Xansi option is specified.

(26) Type modifiers - const

If an object defined with a const modifier is modified using an lvalue that is the non-const modified version, then it is undefined.

(27) Type modifiers - volatile

If an object defined with a const modifier is modified using an lvalue that is the non-const modified version, then it is undefined.

(28) return statements

A message will be output if a return statement without an expression is executed, and the caller uses the return value of the function, and there is a declaration. If there is no declaration, then the return value of the function will be undefined.

(29) Function definitions

If a function taking a variable number of arguments is defined without a parameter type list that ends with an ellipsis, then the values of the formal parameters will be undefined.

(30) Conditional inclusion

If a replacement operation generates a "defined" token, or if the usage of the "defined" unary operator before macro replacement does not match one of the two formats specified in the constraints, then it will be handled as an ordinary "defined".

(31) Macro replacement - arguments not containing preprocessing tokens

A message is output if the arguments (before argument replacement) do not contain preprocessing tokens.

(32) Macro replacement - arguments with preprocessing directives

A message is output if an argument list contains a preprocessor token stream that would function as a processing directive in another circumstance.

(33) # operator

A message is output if the results of replacement are not a correct simple string literal.

(34) ## operator

A message is output if the results of replacement are not a correct simple string literal.

3.1.3 Processing system dependent items

This section explains items dependent on processing system in the ANSI standards.

(1) Data types and sizes

The byte order in a word (4 bytes) is "from least significant to most significant byte" Signed integers are expressed by 2's complements. The sign is added to the most significant bit (0 for positive or 0, and 1 for negative).

- The number of bits of 1 byte is 8.
- The number of bytes, byte order, and encoding in an object files are stipulated below.

Table 3-1. Data Types and Sizes

Data Types	Sizes
char	1 byte
short	2 bytes

Data Types	Sizes
int, long, float	4 bytes
double, long double, long long	8 bytes
pointer	Same as unsigned int

(2) Translation stages

The ANSI standards specify eight translation stages (known as "phases") of priorities among syntax rules for translation. The arrangement of "non-empty white space characters excluding line feed characters" which is defined as processing system dependent in phase 3 "Decomposition of source file into preprocessing tokens and white space characters" is maintained as it is without being replaced by single white space character.

(3) Diagnostic messages

When syntax rule violation or restriction violation occurs on a translation unit, the compiler outputs as error message containing source file name and (when it can be determined) the number of line containing the error. These error messages are classified: "Warning", "Abort error", "Fatal error" and "other" messages. For output formats of messages, see the "CubeSuite+ Integrated Development Environment User's Manual: Message".

(4) Program startup processing

The name and type of a function that is called on starting program processing are not stipulted.
Therefore, it is dependent on the user-own coding and target system.

(5) Program execution

The configuration of the interactive unit is not stipulated.
Therefore, it is dependent on the user-own coding and target system.

(6) Character set

The values of elements of the execution environment character set are ASCII codes.

(7) Multi-byte characters

Supported multi-byte characters are ECU, SJIS, UTF-8, big5 and gb2312.
Japanese and Chinese description in comments and character strings is supported.

(8) Significance of character display

The values of expanded notation are stipulated as follows.

Table 3-2. Expanded Notation and Meaning

Expanded Notation	Value (ASCII)	Meaning
\a	07	Alert (Warning tone)
\b	08	Backspace
\f	0C	Form feed (New Page)
\n	0A	New line (Line feed)
\r	0D	Carriage return (Restore)
\t	09	Horizontal tab
\v	0B	Vertical tab

(9) Translation limit

There are no limits on translation. The maximum translatable value depends on the memory of the host machine on which the program is running.

(10) Quantitative limit

(a) The limit values of the general integer types (limits.h file)

The limits.h file specifies the limit values of the values that can be expressed as general integer types (char type, signed/unsigned integer type, and enumerate type).

Because multi-byte characters are not supported, MB_LEN_MAX does not have a corresponding limit. Consequently, it is only defined with MB_LEN_MAX as 1.

The limit values defined by the limits.h file are as follows.

Table 3-3. Limit Values of General Integer Type (limits.h File)

Name	Value	Meaning
CHAR_BIT	+8	The number of bits (= 1 byte) of the minimum object not in bit field
SCHAR_MIN	-128	Minimum value of signed char
SCHAR_MAX	+127	Maximum value of signed char
UCHAR_MAX	+255	Maximum value of unsigned char
CHAR_MIN	-128	Minimum value of char
CHAR_MAX	+127	Maximum value of char
SHRT_MIN	-32768	Minimum value of short int
SHRT_MAX	+32767	Maximum value of short int
USHRT_MAX	+65535	Maximum value of unsigned short int
INT_MIN	-2147483648	Minimum value of int
INT_MAX	+2147483647	Maximum value of int
UINT_MAX	+4294967295	Maximum value of unsigned int
LONG_MIN	-2147483648	Minimum value of long int
LONG_MAX	+2147483647	Maximum value of long int
ULONG_MAX	+4294967295	Maximum value of unsigned long int
LLONG_MIN	-9223372036854775807	Minimum value of long long int
LLONG_MAX	+9223372036854775807	Maximum value of long long int
ULLONG_MAX	+18446744073709551615	Maximum value of unsigned long long int

(b) The limit values of the floating-point type (float.h file)

The limit values related to characteristics of the floating-point type are defined in float.h file.

The limit values defined by the float.h file are as follows.

Table 3-4. Definition of Limit Values of Floating-point Type (float.h File)

Name	Value	Meaning
FLT_ROUNDS	+1	Rounding mode for floating-point addition. 1 for the RH850 family (rounding in the nearest direction).
FLT_RADIX	+2	Radix of exponent (b)
FLT_MANT_DIG	+24	Number of numerals (p) with FLT_RADIX of floating- point mantissa as base
DBL_MANT_DIG	+53	
LDBL_MANT_DIG	+53	
FLT_DIG	+6	Number of digits of a decimal number (q) that can round a decimal number of q digits to a floating-point number of p digits of the radix b and then restore the decimal number of q
DBL_DIG	+15	
LDBL_DIG	+15	
FLT_MIN_EXP	-125	Minimum negative integer (e_{min}) that is a normalized floating-point number when FLT_RADIX is raised to the power of the value of FLT_RADIX minus 1.
DBL_MIN_EXP	-1021	
LDBL_MIN_EXP	-1021	
FLT_MIN_10_EXP	-37	Minimum negative integer$\log_{10} b^{e_{min-1}}$ that falls in the range of a normalized floating-point number when 10 is raised to the power of its value.
DBL_MIN_10_EXP	-307	
LDBL_MIN_10_EXP	-307	
FLT_MAX_EXP	+128	Maximum integer (e_{max}) that is a finite floating-point number that can be expressed when FLT_RADIX is raised to the power of its value minus 1.
DBL_MAX_EXP	+1024	
LDBL_MAX_EXP	+1024	
FLT_MAX_10_EXP	+38	Maximum integer that falls in the range of a normalized floating-point number when 10 is raised to this power. $\log_{10} ((1 - b^{-p}) * b^{e_{maxx}})$
DBL_MAX_10_EXP	+308	
LDBL_MAX_10_EXP	+308	
FLT_MAX	3.40282347E + 38F	Maximum value of finite floating-point numbers that can be expressed $(1 - b^{-p}) * b^{e_{max}}$
DBL_MAX	1.7976931348623158E+308	
LDBL_MAX	1.7976931348623158E+308	
FLT_EPSILON	1.19209290E - 07F	Difference between 1.0 that can be expressed by specified floating-point number type and the lowest value which is greater than 1. $b^{1 - p}$
DBL_EPSILON	2.2204460492503131E-016	
LDBL_EPSILON	2.2204460492503131E-016	
FLT_MIN	1.17549435E - 38F	Minimum value of normalized positive floating-point number $b^{e_{min - 1}}$
DBL_MIN	2.2250738585072014E-308	
LDBL_MIN	2.2250738585072014E-308	

(11) Identifier

All identifiers are considered to have meaning. There are no restrictions on identifier length.

Uppercase and lowercase characters are distinguished.

(12) char type

If a value larger than a char is stored in a char type, then the value is converted to type char.
A char type with no type specifier (signed, unsigned) specified is treated as a signed integer as the default assumption.

```
char    c = '\777';     /*Value of c is -1.*/
```

(13) Floating-point constants

The floating-point constants conform to IEEE754[Note].

Note IEEE: Institute of Electrical and Electronics Engineers
IEEE754 is a system for handling floating-point calculations, providing a uniform standard for data formats, numerical ranges, and the like handled.

(14) Character constants

(a) Both the character set of the source program and the character set in the execution environment are basically ASCII codes, and correspond to members having the same value.
However, for the character set of the source program, character codes in Japanese can be used (see "(8) Significance of character display").

(b) The last character of the value of an integer character constant including two or more characters is valid.

(c) A character that cannot be expressed by the basic execution environment character set or escape sequence is expressed as follows.

<1> An octal or hexadecimal escape sequence takes the value indicated by the octal or hexadecimal notation

\777	511

<2> The simple escape sequence is expressed as follows.

\'	'
\"	"
\?	?
\\	\

<3> Values of \a, \b, \f, \n, \r, \t, \v are same as the values explained in "(8) Significance of character display".

(d) Character constants of multi byte characters are not supported.

(15) Character string

A character string can be described in Japanese and Chinese.
The default character code is Shift JIS.
A character code in input source file can be selected by using the -Xcharacter_set option of the CC-RH.

```
-Xcharacter_set=[none | euc_jp | sjis | utf8 | big5 | gb2312]
```

(16) Header file name

The method to reflect the string in the two formats (< > and " ") of a header file name on the header file or an external source file name is stipulated in "(33) Loading header file".

(17) Comment

A comment can be described in Japanese and Chinese. The character code is the same as the character string in "(15) Character string".

(18) Signed constants and unsigned constants

If the value of a general integer type is converted into a signed integer of a smaller size, the higher bits are truncated and a bit string image is copied.
If an unsigned integer is converted into the corresponding signed integer, the internal representation is not changed.

(19) Floating-points and general integers

If the value of a general integer type is converted into the value of a floating-point type, and if the value to be converted is within a range that can be expressed but not accurately, the result is rounded to the closest expressible value.

(20) double type and float type

When casting a double to a float, or a long double to a double or a float, if the typecast value cannot be represented accurately in the available value range, then the result will be rounded to the nearest value that can be represented.

(21) Signed type in operator in bit units

The characteristics of the shift operator conform to the stipulation in "(27) Shift operator in bit units".
The other operators in bit units for signed type are calculated as unsigned values (as in the bit image).

(22) Members of structures and unions

If the value of a union member is stored in a different member, the value will be stored in accordance with the alignment condition. As a result, access to members of the union will be of the subsequently accessed type.

(23) sizeof operator

The value resulting from the "sizeof" operator conforms to the stipulation related to the bytes in an object in "(1) Data types and sizes".
For the number of bytes in a structure and union, it is byte including padding area.

(24) Cast operator

When a pointer is converted into a general integer type, the required size of the variable is the same as the size of the unsigned long type. The bit string is saved as is as the conversion result.
Also, although it is possible to typecast an arbitrary integer to a pointer, after the integer is typecast to a pointer, the integer's bit pattern is retained unchanged.

(25) Division/remainder operator

The result of the division operator ("/") when the operands are negative and do not divide perfectly with integer division, is as follows: If either the divisor or the dividend is negative, the result is the smallest integer greater than the algebraic quotient.

If both the divisor and the dividend are negative, the result is the largest integer less than the algebraic quotient.

If the operand is negative, the result of the "%" operator takes the sign of the first operand in the expression.

(26) Addition and subtraction operators

If two pointers indicating the elements of the same array are subtracted, the type of the result is unsigned long type.

(27) Shift operator in bit units

If E1 of "E1 >> E2" is of signed type and takes a negative value, an arithmetic shift is executed.

(28) Storage area class specifier

Optimize for the fastest possible access, regardless of whether there is a storage-class area specifier "register" declaration.

(29) Structure and union specifier

(a) A simple int type bit field without signed or unsigned appended is treated as a signed field, and the most significant bit is treated as the sign bit.

(b) To retain a bit field, a storage area unit to which any address with sufficient size can be assigned can be allocated. If there is insufficient area, however, the bit field that does not match is packed into to the next unit according to the alignment condition of the type of the field.
The allocation sequence of the bit field in unit is from lower to higher.

(c) Each member of the non-bit field of one structure or union is aligned at a boundary as follows:

char, unsigned char type, and its array	Byte boundary
short, unsigned short type, and its array	2-byte boundary
Others (including pointer)	4-byte boundary

If packing is used, however, the boundaries of all members will be the byte boundary.

(30) Enumerate type specifier

The type of an enumeration specifier is signed int.

However, when the -Xenum_type=auto option is specified, each enumerated type is treated as the smallest integer type capable of expressing all the enumerators in that type.

(31) Type qualifier

The configuration of access to data having a type qualified to be "volatile" is dependent upon the address (I/O port, etc.) to which the data is mapped. If packing is used, however, the boundaries of all members will be the byte boundary.

(32) Condition embedding

(a) The value for the constant specified for condition embedding and the value of the character constant appearing in the other expressions are equal.

(b) A single-character character constant cannot have a negative value.

(33) Loading header file

(a) A preprocessing directive in the form of "#include <character string>"

A preprocessing directive in the form of "#include <character string>" searches for a header file from the folder specified by the -I option if "character string" does not begin with "\"[Note], and then searches standard include file folder (..\inc folder with a relative path from the bin folder where the ccrh is placed).
If a header file uniformly identified is searched with a character string specified between delimiters "<" and ">", the whole contents of the header file are replaced.

Note "/" are regarded as the delimiters of a folder.

Example

```
#include    <header.h>
```

The search order is as follows.
- Folder specified by -I
- Standard include file folder

(b) A preprocessing directive in the form of "#include "character string""

A preprocessing directive in the form of "#include "character string"" searches for a header file from the folder where the source file exists, then searches specified folder (-I option) and then searches standard include file folder (..\inc folder with a relative path from the bin folder where the ccrh is placed).
If a header file uniformly identified is searched with a character string specified between delimiters " " " and " " ", the whole contents of the header file are replaced.

Example

```
#include    "header.h"
```

The search order is as follows.
- Folder where source file exists
- Folder specified by -I
- Standard include file folder

(c) The format of "#include preprocessing character phrase string"

The format of "#include preprocessing character phrase string" is treated as the preprocessing character phrase of single header file only if the preprocessing character phrase string is a macro that is replaced to the form of <character string> or "character string".

(d) A preprocessing directive in the form of "#include <character string>"

Between a string delimited (finally) and a header file name, the length of the alphabetic characters in the strings is identified,

And the file name length valid in the compiler operating environment is valid.

The folder that searches a file conforms to the above stipulation.

(34) #pragma directive

The CC-RH can specify the following #pragma directives.

(a) Data or program memory allocation

```
#pragma section section-type ["section-name"]
```

Allocates variables to an arbitrary section.
For details about the allocation method, see "(1) Allocation of data and program to section".

(b) Describing assembler instruction

```
#pragma inline_asm
```

Assembler directives can be described in a C source program.
For the details of description, see "(2) Describing assembler instruction".

(c) Inline expansion specification

```
#pragma inline [(]function-name[, function-name ...][)]
#pragma noinline [(]function-name[, function-name ...][)]
```

A function that is expanded inline can be specified.
For the details of expansion specification, see "(3) Inline expansion".

(d) Interrupt/exception handler specification

```
#pragma interrupt interrupt-request-name function-name [allocation-method]  [Option
[Option]...]
```

Interrupt/Exception handlers are described in C language.
For the details of description, see "(c) Describing interrupt/exception handler".

(e) Interrupt disable function specification

```
#pragma block_interrupt [(]function-name[)]
```

Interrupts are disabled for the entire function.
For details of description, see "(b) Disabling interrupts in entire function".

(f) Structure type packing specification

```
#pragma pack [()[1|2|4][)]
```

Specifies the packing of a structure type. The packing value, which is an alignment value of the member, is specified as the numeric value. A value of 1, 2, 4 can be specified. When the numeric value is not specified, it is by default alignment.
For details of description, see "(8) Structure type packing".

(g) Specifying bit field assignment

```
#pragma bit_order [{left|right}]
```

This specifies a change to the order of the bit field.
For details of description, see "(9) Bit field assignment".

(h) Core number specification (for a multi-core device)

```
#pragma pmodule pm-specification
```

A function to which a core number is to be assigned can be specified.
For details of description, see "(10) Core number specification (for a multi-core device)".

(35) Predefined macro names

All the following macro names are supported.

Table 3-5. List of Supported Macros

Macro Name	Definition
__LINE__	Line number of source line at that point (decimal).
__FILE__	Name of source file (character string constant).
__DATE__	Date of translating source file (character string constant in the form of "Mmm dd yyyy"). Here, the name of the month is the same as that created by the asctime function stipulated by ANSI standards (3 alphabetic characters with only the first character is capital letter) (The first character of dd is blank if its value is less than 10).
__TIME__	Translation time of source file (character string constant having format "hh:mm:ss" similar to the time created by the asctime function).
__STDC__	Decimal constant 1 (defined when the -Xansi option is specified).[Note]
__RENESAS__	This value is not set.
__RENESAS_VERSION__	If the version is V.XX.YY.ZZ, this will be 0xXXYYZZ00. Example) V.1.00.00 -> -D__RENESAS_VERSION__=0x01000000
__CCRH__	This value is not set .
__CCRH	This value is not set.
__RH850__	This value is not set.
__RH850	This value is not set.

Macro Name	Definition
__v850e3v5__	This value is not set (defined when v850e3v5 or rh850 is specified by the -Xcommon option is specified).
__v850e3v5	This value is not set (defined when v850e3v5 or rh850 is specified by the -Xcommon option is specified).
__DBL8	This value is not set.
__DOUBLE_IS_64BITS__	This value is not set.
__BITLEFT	This value is not set (defined when left is specified by the -Xbit_order option).
__BITRIGHT	This value is not set (defined when right is specified by the -Xbit_order option).
__AUTO_ENUM	This value is not set (defined when auto is specified by the -Xenum_type option).
__FPU	This value is not set (defined when fpu is specified by the -Xfloat option).
__CHAR_SIGNED__	This value is not set..
Register mode macro	Since this macro indicates the target CPU, its value is not set. Macro defined with register mode is as follows. 32 register mode: __reg32__ 22 register mode: __reg22__ Universal register mode: __reg_common__
_LIT	This value is not set.
__MULTI_LEVEL__	level value designated in Xmulti_level = level

Note For the processing to be performed when the -Xansi option is specified, see "3.1.5 Option to process in strict accordance with ANSI standard".

3.1.4 C99 language function

This section describes the C99 language functions supported by the CC-RH.

(1) Comment by //

Text from two slashes (//) until a newline character is a comment. If there is a backslash character (\) immediately before the newline, then the next line is treated as a continuation of the current comment.

(2) Concatenating wide character strings

The result of concatenating a character string constant with a wide character string constant is a wide character string constant.

(3) _Bool type

_Bool type is supported.

(4) long long int type

long long int type is supported. long long int type is 8-byte of integer type.
Appending "LL" to a constant value is also supported. It is also possible to specify this for bit field types.

(5) Integer promotion

In accordance with support for types _Bool and long long, integer promotion is also in accordance with the C99 specification.

(6) Existing argument expansion

In accordance with support for types _Bool and long long, existing argument expansion is also in accordance with the C99 specification..

- Functions are called after expanding type _Bool_ to type int (4 bytes).
- Functions are called with type (unsigned) long long remaining as an 8 bytes value.

(7) Comma permission behind the last enumeration child of a enum definition

When defining an enum type, it is permissible for the last enumerator in the enumeration to be followed by a comma (,).

```
enum EE {a, b, c,};
```

(8) Inline keyword (inline function)

Inline keyword is supported.

This can also be specified using a pragma directive, via the following format.

```
#pragma inline [()function-name[, function-name, ...][)]
```

For the details of expansion specification, see "(3) Inline expansion".

(9) Types of integer constants

In accordance with the addition of type long long, the types of integer constants are as follows.

The type of an integer constant will be the first type in the lists below capable of representing that value.

Table 3-6. Types of Integer Constants (If type long long is enabled (when -Xansi is not specified))

Suffix	Decimal Constant	Octal Constant or Hexadecimal
None	int long int unsigned long int[Note] long long int	int unsigned int long int unsigned long int long long int unsigned long long int
u or U	unsigned int unsigned long int unsigned long long int	unsigned int unsigned long int unsigned long long int
l or L	long int long long int	long int unsigned long int long long int unsigned long long int
Both u or U, and l or L	unsigned long int unsigned long long int	unsigned long int unsigned long long int
ll or LL	long long int	long long int unsigned long long int
Both u or U, and ll or LL	unsigned long long int	unsigned long long int

Note Different from C99 specification

Table 3-7. Types of Integer Constants (If type long long is disabled (when -Xansi is specified))

Suffix	Decimal Constant	Octal Constant or Hexadecimal
None	int long int unsigned long int	int unsigned int long int unsigned long int
u or U	unsigned int unsigned long int	unsigned int unsigned long int
l or L	long int	long int unsigned long int
Both u or U, and l or L	unsigned long int	unsigned long int

3.1.5 Option to process in strict accordance with ANSI standard

If the -Xansi option is specified to CC-RH, it will perform processing in strict accordance with the ANSI standard. The differences between when the -Xansi option is specified and when not specified are as follows.

Table 3-8. Processing When -Xansi Option Strictly Conforming to Language Specifications is Specified

Item	With -Xansi Specification	Without -Xansi Specification
Bit field	An error[Note 1] occurs if type other than int is specified for bit field.	Specification of types other than int is allowed.
# line number	An error occurs.	Treated in same manner as "#line line number".[Note 2]
Parameters of functions declared with #pragma inline	If the type of a return value or parameter is different but type conversion is possible between the specified function call and definition, then an error will occur.	The type of the return value is converted to the type at the call site, the parameters are converted to the type of the function definition, and inline expansion is performed.
__STDC__	Defines value as macro with value 1.	Does not define.
_Bool type long long type	An error occurs.	Specification is allowed.
Structure and union specifiers	If the member declaration list does not include named members, then an error message will be output indicating that the list has no effect.	If the member declaration list does not include named members, then an warning message will be output indicating that the list has no effect.

Notes 1. Normal error beginning with "E". The same applies hereafter.

2. See the ANSI standards.

3.1.6 Internal representation and value area of data

This section explains the internal representation and value area of each type for the data handled by the CC-RH.

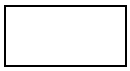
(1) Integer type

(a) Internal representation

The leftmost bit in an area is a sign bit with a signed type (type declared without "unsigned"). The value of a signed type is expressed as 2' s complement.

Figure 3-1. Internal Representation of Integer Type

_Bool

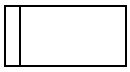


Only the 0th bit has meaning. Bits 1 to 7 are undefined.

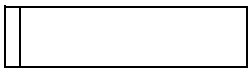
When the -Xansi option is used, _Bool type will cause a C90 violation error.

char

signed char (no sign bit for unsigned)

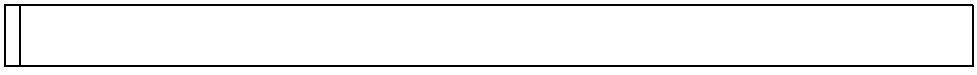


short (no sign bit for unsigned)



int, long (no sign bit for unsigned)

long long (no sign bit for unsigned)



When the -Xansi option is used, long long type will cause a C90 violation error.

(b) Value area

Table 3-9. Value Area of Integer Type

Type	Value Area
char[Note]	-128 to +127
short	-32768 to +32767
int	-2147483648 to +2147483647
long	-2147483648 to +2147483647
long long	-9223372036854775808 to +9223372036854775807
unsigned char	0 to 255
unsigned short	0 to 65535
unsigned int	0 to 4294967295
unsigned long	0 to 4294967295
unsigned long long	0 to 18446744073709551615

(2) Floating-point type

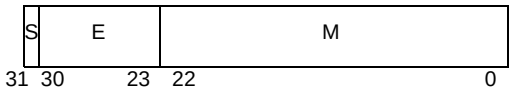
(a) Internal representation

Internal Representation of floating-point data type conforms to IEEE754[Note]. The leftmost bit in an area of a sign bit. If the value of this sign bit is 0, the data is a positive value; if it is 1, the data is a negative value.

Note IEEE**:** Institute of Electrical and Electronics Engineers
IEEE754 is a standard to unify specifications such as the data format and numeric range in systems that handle floating-point operations.

Figure 3-2. Internal Representation of Floating-Point Type

float

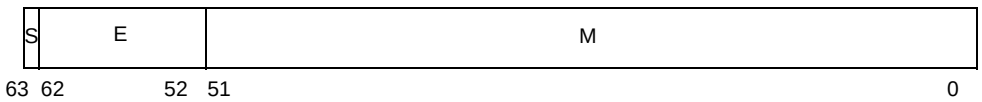


S: Sign bit of mantissa

E: Exponent (8 bits)

M: Mantissa (23 bits)

double



S: Sign bit of mantissa

E: Exponent (11 bits)

M: Mantissa (52 bits)

(b) Value area

Table 3-10. Value Area of Floating-Point Type

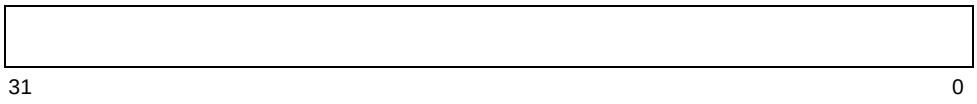
Type	Value Area
float	1.17549435E-38F to 3.40282347E+38F
double	2.2250738585072014E-308 to 1.7976931348623158E+308
long double	2.2250738585072014E-308 to 1.7976931348623158E+308

(3) Pointer type

(a) Internal representation

The internal representation of a pointer type is the same as that of an unsigned int type.

Figure 3-3. Internal Representation of Pointer Type

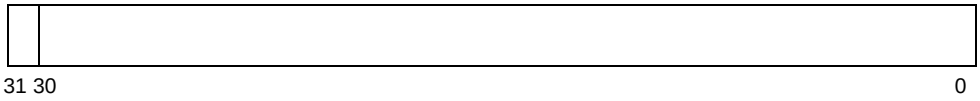


(4) Enumerate type

(a) Internal representation

The internal representation of an enumerate type is the same as that of a signed int type. The leftmost bit in an area of a sign bit.

Figure 3-4. Internal Representation of Enumerate Type



When the -Xenum_type=auto option is specified, see "(30) Enumerate type specifier".

(5) Array type

(a) Internal representation

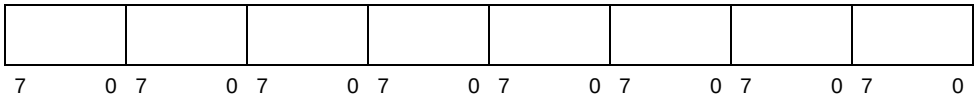
The internal representation of an array type arranges the elements of an array in the form that satisfies the alignment condition (alignment) of the elements

Example

```
char    a[8] = {1, 2, 3, 4, 5, 6, 7, 8};
```

The internal representation of the array shown above is as follows.

Figure 3-5. Internal Representation of Array Type



(6) Structure type

(a) Internal representation

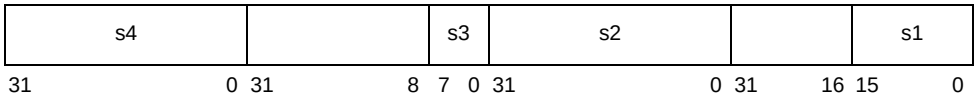
The internal representation of a structure type arranges the elements of a structure in a form that satisfies the alignment condition of the elements.

Example

```
struct {
        short   s1;
        int     s2;
        char    s3;
        long    s4;
} tag;
```

The internal representation of the structure shown above is as follows.

Figure 3-6. Internal Representation of Structure Type



For the internal representation when the structure type packing function is used, see "(8) Structure type packing".

(7) Union type

(a) Internal representation

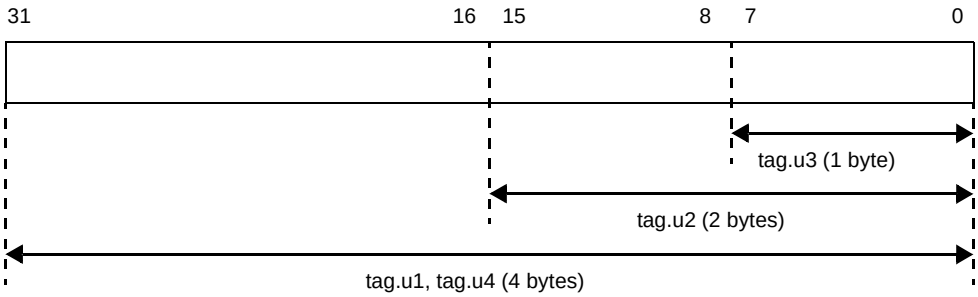
A union is considered as a structure whose members all start with offset 0 and that has sufficient size to accommodate any of its members. The internal representation of a union type is like each element of the union is placed separately at the same address.

Example

```
union {
        int     u1;
        short   u2;
        char    u3;
        long    u4;
} tag;
```

The internal representation of the union shown in the above example is as follows.

Figure 3-7. Internal Representation of Union Type



(8) Bit field

(a) Internal representation

The most significant bit of a bit field declared as a signed type, or without an explicit sign declaration, will be the sign bit. The first bit field to be declared will be allocated starting from the least significant bit in the area with the sign of the type when the bit field was declared. If the alignment condition of the type specified in the declaration of a bit field is exceeded as a result of allocating an area that immediately follows the area of the preceding bit field to the bit field, the area is allocated starting from a boundary that satisfies the alignment condition.

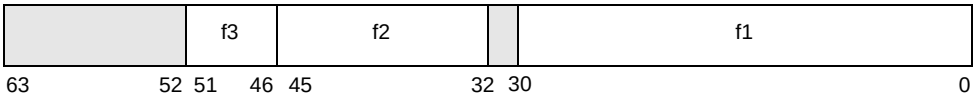
You can allocate the members of a bit field starting from the most significant bit using the -Xbit_order=left option or by specifying #pragma bit_order left. See "(9) Bit field assignment" or "CubeSuite+ Integrated Development Environment User's Manual: RH850 Build" for details.

Examples 1.

```
struct {
        unsigned int    f1:30;
        int             f2:14;
        unsigned int    f3:6;
} flag;
```

The internal representation for the bit field in the above example is as follows.

Figure 3-8. Internal Representation of Bit Field

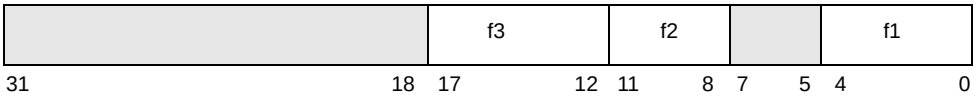


2.

```
struct {
    int             f1:5;
    char            f2:4;
    int             f3:6;
} flag;
```

The internal representation for the bit field in the above example is as follows.

Figure 3-9. Internal Representation of Bit Field



The ANSI standards do allow only int and unsigned int types to be specified for a bit field, but the CC-RH allows char, short, long, long long and those unsigned types.
For the internal representation of bit field when the structure type packing function is used, see "(8) Structure type packing".

(9) Alignment condition

(a) Alignment condition for basic type

Alignment condition for basic type is as follows.
If the -Xinline_strcpy option of the CC-RH is specified, however, all the arrey types are 4-byte boundaries.

Table 3-11. Alignment Condition for Basic Type

Basic Type	Alignment Conditions
(unsigned) char and its array type _Bool type	Byte boundary
(unsigned) short and its array type	2-byte boundary
Other basic types (including pointer) (unsigned) long long and its array type double and its array type	4-byte boundary
long double and its array type	4-byte boundary

(b) Alignment condition for union type

The alignment conditions for a union type are the same as those of the structure's member whose type has the largest alignment condition.

Here are examples of the respective cases:

Examples 1.

```
union  tug1 {
  unsigned short i; /*2 bytes member*/
  unsigned char  c; /*1 bytes member*/
};  /*The union is aligned with 2-byte.*/
```

2.

```
union  tug2 {
  unsigned int  i;  /*4 bytes member*/
  unsigned char  c; /*1 byte member*/
};  /*The union is aligned with 4-byte.*/
```

(c) Alignment condition for structure type

The alignment conditions for a structure type are the same as those of the structure's member whose type has the largest alignment condition.

Here are examples of the respective cases:

Examples 1.

```
struct  ST {
        char    c;      /*1 byte member*/
};  /*Structure is aligned with 1-byte.*/
```

2.

```
struct  ST {
        char    c;      /*1 byte member*/
        short   s;      /*2 bytes member*/
};  /*Structure is aligned with 2-byte.*/
```

3.

```
struct  ST {
        char    c;      /*1 byte member*/
        short   s;      /*2 bytes member*/
        short   s2;     /*2 bytes member*/
};  /*Structure is aligned with 2-byte.*/
```

4.

```
struct  ST {
        char    c;      /*1 byte member*/
        short   s;      /*2 bytes member*/
        int     i;      /*4 bytes member*/
};  /*Structure is aligned with 4-byte.*/
```

5.

```
struct  ST {
        char        c;      /*1 byte member*/
        short       s;      /*2 bytes member*/
        int         i;      /*4 bytes member*/
        long long   ll;     /*4 bytes member*/
};  /*Structure is aligned with 4-byte.*/
```

(d) Alignment condition for function argument

The alignment condition for a function argument is a 4-byte boundary.

(e) Alignment condition for executable program

The alignment condition when an executable object module file is created by linking object files is 2-byte boundary.

3.1.7 Section name

The following table lists the names, section types, and section attributes of these reserved sections.

Table 3-12. Reserved Sections

Section Type	Default Section Name	Description	Section Type	Section Attribute	Alignment Size
Program areas	.text	Executable program	SHT_PROGBITS	SHF_ALLOC + SHF_EXECINSTR	2
Uninitialized data areas	.bss	Sections accessed with r0-relative ld/st (two instructions)	SHT_NOBITS	SHF_ALLOC + SHF_WRITE	4
	.zbss .zbss23	Sections that can be accessed with r0-relative ld/st instruction Generation when #pragma section r0_disp* is specified			
	.ebss .ebss23	Sections that can be accessed with ep-relative ld/st instruction Generation when #pragma section ep_disp* is specified			
	.tbss4 .tbss5 .tbss7 .tbss8	Sections that can be accessed with ep-relative sld/sst instruction Generation when #pragma section ep_disp* is specified			
	.sbss .sbss23	Sections that can be accessed with gp-relative ld/st instruction Generation when #pragma section gp_disp* is specified			
Initialized data areas	.data	Sections accessed with r0-relative ld/st (two instructions)	SHT_PROGBITS	SHF_ALLOC + SHF_WRITE	4
	.zdata .zdata23	Sections that can be accessed with r0-relative ld/st instruction Generation when #pragma section r0_disp* is specified			
	.edata .edata23	Sections that can be accessed with ep-relative ld/st instruction Generation when #pragma section ep_disp* is specified			
	.tdata4 .tdata5 .tdata7 .tdata8	Sections that can be accessed with ep-relative sld/sst instruction Generation when #pragma section ep_disp* is specified			
	.sdata .sdata23	Sections that can be accessed with gp-relative ld/st instruction Generation when #pragma section gp_disp* is specified			

Section Type	Default Section Name	Description	Section Type	Section Attribute	Alignment Size
Constant data areas	.const	Sections accessed with r0-relative ld/st (two instructions)	SHT_PROGBITS	SHF_ALLOC	4
	.zconst	Sections that can be accessed with r0-relative ld/st instruction Generation when #pragma section .zconst* is specified			
	.zconst23				

The default section name can be changed using #pragma section.

3.1.8 Register mode

The CC-RH provides three register modes. By specifying these register modes efficiently, the contents of some registers do not need to be saved or restored when an interrupt occurs or the task is switched. As a result, the processing speed can be improved. The register modes are specified by using the register mode specification option (-Xreg_mode) of the CC-RH. This function reduces the number of registers internally used by the CC-RH on a step-by-step basis. As a result, the following effects can be expected:

- The registers not used can be used for the application program (that is, a source program in assembly language).
- The overhead required for saving and restoring registers can be reduced.

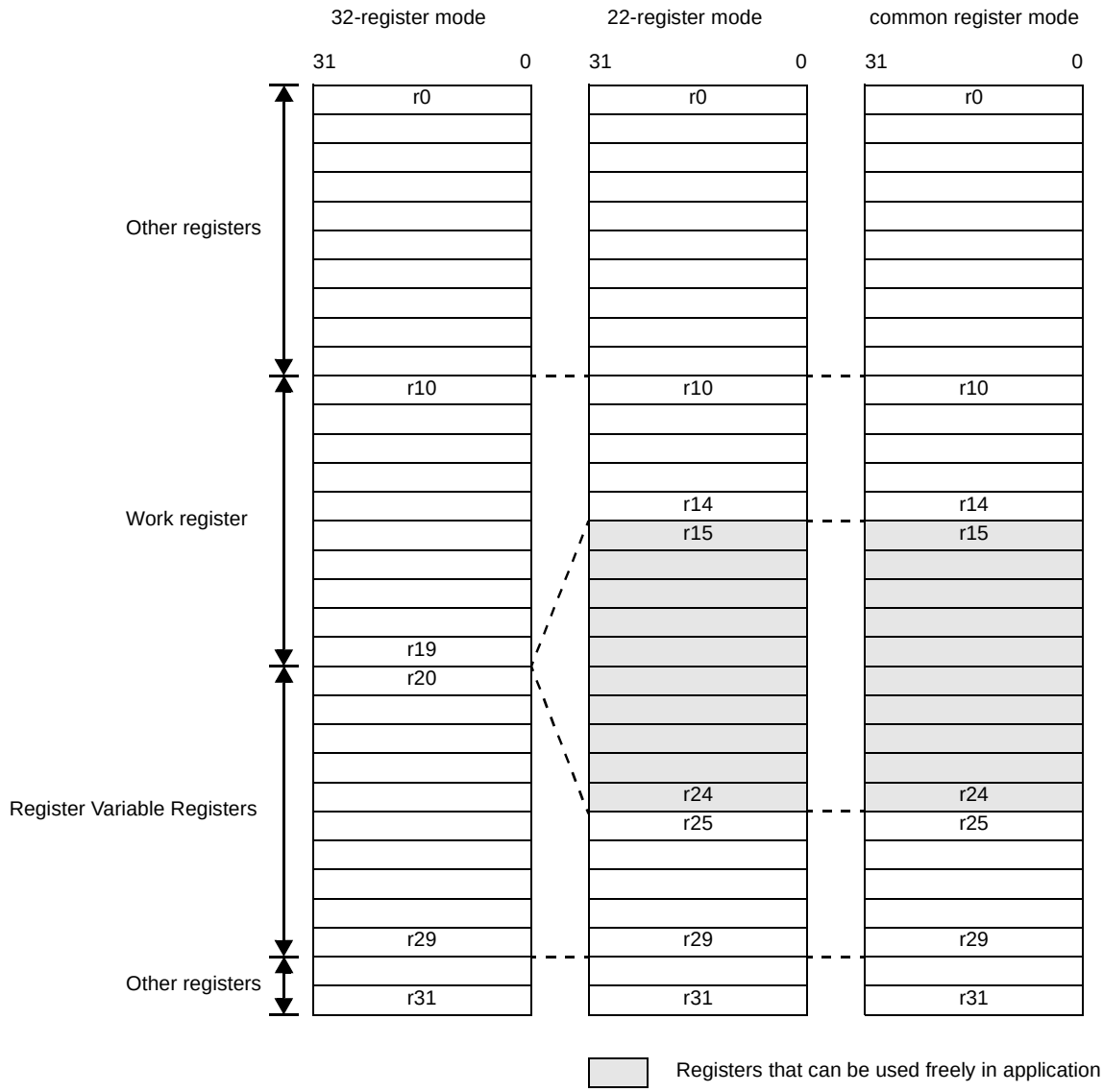
Caution In an application program that has many variables to be allocated to registers by the CC-RH, the variables so far allocated to a register are accessed from memory when a register mode has been specified. As a result, the processing speed may drop.

Next table and next Figure show the three register modes supplied by the CC-RH.

Table 3-13. Register Modes Supplied by CC-RH

Register Modes	Work Registers	Register Variable Registers
32-register mode (Default)	r10 to r19	r20 to r29
22-register mode	r10 to r14	r25 to r29
common register mode	r10 to r14	r25 to r29

Figure 3-10. Register Modes and Usable Registers



Specification example on command line

```
> ccrh -Xreg_mode=22 file.c <- compiled in 22-register mode
```

3.2 Extended Language Specifications

This section explains the extended language specifications supported by the CC-RH.

3.2.1 Macro name

Below are #pragma directives supported as extended language specifications.

Table 3-14. List of Supported Macros

Macro Name	Definition
__LINE__	Line number of source line at that point (decimal).
__FILE__	Name of source file (character string constant).
__DATE__	Date of translating source file (character string constant in the form of "Mmm dd yyyy"). Here, the name of the month is the same as that created by the asctime function stipulated by ANSI standards (3 alphabetic characters with only the first character is capital letter) . The first character of dd is blank if its value is less than 10.
__TIME__	Translation time of source file (character string constant having format "hh:mm:ss" similar to the time created by the asctime function).
__STDC__	Decimal constant 1 (defined when the -Xansi option is specified).Note
__RENESAS__	This value is not set.
__RENESAS_VERSION__	If the version is V.XX.YY.ZZ, this will be 0xXXYYZZ00. Example) V.1.00.00 -> -D__RENESAS_VERSION__=0x01000000
__CCRH__	This value is not set .
__CCRH	This value is not set .
__CC850__	This value is not set.
__CC850	This value is not set.
__v850e3v5__	This value is not set (defined when v850e3v5 or rh850 is specified by the -Xcommon option is specified).
__v850e3v5	This value is not set (defined when v850e3v5 or rh850 is specified by the -Xcommon option is specified).
__DBL8	This value is not set .
__DOUBLE_IS_64BITS__	This value is not set.
__BITLEFT	This value is not set (defined when left is specified by the -Xbit_order option).
__BITRIGHT	This value is not set (defined when right is specified by the -Xbit_order option).
__AUTO_ENUM	This value is not set (defined when auto is specified by the -Xenum_type option).
__FPU	This value is not set (defined when fpu is specified by the -Xfloat option).
__CHAR_SIGNED__	This value is not set.).
Register mode macro	Since this macro indicates the target CPU, its value is not set. Macro defined with register mode is as follows. 32 register mode: __reg32__ 22 register mode: __reg22__ Universal register mode: __reg_common__
_LIT	This value is not set.
__MULTI_LEVEL__	level value designated in Xmulti_level = level

Note For the processing to be performed when the -Xansi option is specified, see "3.1.5 Option to process in strict accordance with ANSI standard".

3.2.2 Reserved words

The CC-RH adds the following characters as reserved words to implement the expanded function. These words are similar to the ANSI C keywords, and cannot be used as a label or variable name.

Reserved words that are added by the CC-RH are listed below.

_Bool, __bsh, __bsw, __caxi, __clr1, __di, __ei, __halt, __hsw, inline, __ldlw, __ldsr, __mul32, __mul32u, __nop, __not1, __satadd, __satsub, __sch0l, __sch0r, __sch1l, __sch1r, __set1, __set_il, __stcw, __stsr, __synce, __synci, __syncm, __syncp

All names that include two underscores (__) are also invalid as label or variable names.

3.2.3 Compiler generated symbols

The following is a list of symbols generated by the compiler for use in internal processing.
Symbols with the same names as the symbols below cannot be used.

Table 3-15. Compiler Generated Symbols

Target	Generated Symbol
extern function name	*_function name*
static *function name*	*_function name.num*[Note]
extern variable name	*_variable name*
static variable in the file	*_variable name.num*[Note]
static variable in the function	*_variable name.num*[Note]*.function label*
Label in the function	.BB.LABEL.*num1_num2*[Note]
Character string	.STR.*num*
switch table	.SWITCH.LABEL.*num1_num2*[Note] .SWITCH.LABEL.*num1_num2*[Note].END

Note *num*, *num1*, and *num2* are arbitrary numbers.

3.2.4 #pragma directive

Below are #pragma directives supported as extended language specifications.

Table 3-16. List of Supported #pragma Directive

#pragma directive	Definition
#pragma section *attribute-strings* "*section-name*"	Data or program memory allocation
#pragma section *attribute-strings*	
#pragma section [*character string*]	
#pragma inline_asm [()*function-name*[(size=*numerical value*)][,...][)]	Description with assembler instruction
#pragma inline [()*function-name*[, *function-name* ...][)]	Inline expansion
#pragma noinline [()*function-name*[, *function-name*, ...][)]	

#pragma directive	Definition
#pragma interrupt [(]*function-name*[(*interrupt specification* [, *interrupt specification*]...)] [,...] [)]	Interrupt/Exception handler specification
#pragma block_interrupt [(]*function-name*[)]	Interrupt disable function specification
#pragma pack [(][1|2|4][)]	Structure type packing specification
#pragma bit_order [{left|right}]	Bit field assignment
`#pragma pmodule` *`pm-specification`*	Core number specification (for a multi-core device)

(1) Data or program memory allocation

Allocates variables to an arbitrary section.

For details about the allocation method, see "(1) Allocation of data and program to section".

(2) Description with assembler instruction

Assembler directives can be described in a C source program.

For the details of description, see "(2) Describing assembler instruction".

(3) Inline expansion

(a) Inline expansion specification

A function that is expanded inline can be specified.

For the details of expansion specification, see "(3) Inline expansion".

(b) Specifying functions ineligible for inline expansion

You can specify that a function is not eligible for inline expansion.

See "(3) Inline expansion" for details about specifying functions to be ineligible for inline expansion.

(4) Interrupt/Exception handler specification

Interrupt/Exception handlers are described in C language.

For details, see "(c) Describing interrupt/exception handler".

```
#pragma interrupt [(]function-name[(interrupt specification [,interrupt specification]...)] [,...]
[)]
```

(5) Interrupt disable function specification

Interrupts are disabled for the entire function.

For details, see "(b) Disabling interrupts in entire function".

```
#pragma block_interrupt [(]function-name[)]
```

(6) Structure type packing specification

Specifies the packing of a structure type. The packing value, which is an alignment value of the member, is specified as the numeric value. A value of 1, 2, 4 can be specified. When the numeric value is not specified, the setting is the default alignment.

For details, see "(8) Structure type packing".

```
#pragma pack [(][1|2|4][)]
```

(7) Bit field assignment

CC-RH can switch the order of a bit field.Specifies the switching the order of a bit field.

For details, see "(9) Bit field assignment".

```
#pragma bit_order [{left|right}]
```

(8) Core number specification (for a multi-core device)

A function to which a core number is to be assigned can be specified.

For details, see "(10) Core number specification (for a multi-core device)".

```
#pragma pmodule pm-specification
```

3.2.5 Using extended language specifications

This section explains using expanded specifications.

- Allocation of data and program to section
- Describing assembler instruction
- Inline expansion
- Controlling interrupt level
- Interrupt/Exception processing handler
- Disabling or enabling maskable interrupts
- Embedded functions
- Structure type packing
- Bit field assignment
- Core number specification (for a multi-core device)

(1) Allocation of data and program to section

CC-RH can allocate modules and data to arbitrary sections at the C-language level. This makes it possible to specify placement using the relocation attribute characteristics of each section.

(a) #pragma section directive

Describe the #pragma section directive in the following format.

```
#pragma section attribute-strings "section-name"
Variable declaration/definition
```

```
#pragma section attribute-strings
Variable declaration/definition
```

```
#pragma section [character string]
Variable declaration/definition
```

Section relocation attributes are specified using attribute strings, and section names are specified in the form "section-name". All static variables included after this pragma will be placed in the specified section in accordance with the section relocation attribute.

If "attribute string" in the format "#pragma section *attribute-string*" is identical to "character string" in the format "#pragma section [*character-string*]", then it will be treated as the format "#pragma section *attribute-string*" for-

mat, without outputting a message. However, if the -check=shc option is specified, then a message will be output if treated as the "#pragma section *attribute-string*" format.
The identity test of attribute-string and character-string is case sensitive. To give an example, the all-caps string R0_DISP32 will not be treated as an attribute string.

Example

```
#pragma section r0_disp32   /*Here, "data" matches an attribute string, so it is*/
                            /*seen as the format "#pragma section*/
                            /*attribute-string"*/
#pragma section R0_DISP32   /*This does not match the case of an attribute*/
                            /*string, and so it is treated as the format*/
                            /*"#pragma section [character-string]"*/
```

If the section name starts with a number (0-9), an underscore ("_") is prepended to the section name.

Example #pragma section 123 -> Section name : _123.bss, _123.const, _123.text, ...

The following characters can be used in the character string.

- 0 - 9
- a - z, A - Z
- _
- @
- .

If #pragma section is specified for either a declaration or a definition, the one specified with #pragma section is valid.
If different #pragma section directives are specified for declarations or definitions, the #pragma section that appears first is valid.

<1> Specifying "#pragma section *attribute-string* "*section-name*""

Renames the default section, and places variables declared after the #pragma in the new section name.

- This pragma directive renames the default section to the name specified by the user.
- This pragma directive is valid for external variables, string literals, function-internal static variables, and functions.
- This pragma directive invalidates specifications of the same attribute coded prior to this point, and enables the new section specification. If no new section is specified, then it is valid to the end of the file.
- If default is specified as the relocation attribute, then subsequent assignments revert to the default with no #pragma section declared. "default" disables all #pragma section statements.
- If there is no variable initialization, then it is placed in the bss section corresponding to the specified relocation attribute
- By default, string literals are assigned to .const. The placement for #pragma section declarations is the same as for other const objects.
- A section name consists of the user-specified string, followed automatically by a string representing the relocation attribute. Thus depending on whether initialization is enabled, if the relocation attribute is switched automatically, it is possible that a section with the same name will be produced.
  Example: #pragma section r0_disp32 "xxx" -> Section name : xxx.data

- If a const relocation attribute is specified, then only variables with the const modifier are allocated to the section, and variables without this modifier are allocated to the default section.

Table 3-17. Section Relocation Attribute

Target	Renamable Attribute Strings	Default Section Name	User-modified Section Name[Not2]
Definition (type data)	r0_disp16 r0_disp23 r0_disp32 ep_disp4 ep_disp5 ep_disp7 ep_disp8 ep_disp16 ep_disp23 gp_disp16 gp_disp23	.zdata .zdata23 .data .tdata4 .tdata5 .tdata7 .tdata8 .edata .edata23 .sdata .sdata23	*xxx*.zdata *xxx*.zdata23 *xxx*.data *xxx*.tdata4 *xxx*.tdata5 *xxx*.tdata7 *xxx*.tdata8 *xxx*.edata *xxx*.edata23 *xxx*.sdata *xxx*.sdata23
Declaration (type bss)	The compiler automatically determines variable definitions without an initial value to be of type bss. It is thus not a bss attribute string.	.zbss .zbss23 .bss .tbss4 .tbss5 .tbss7 .tbss8 .ebss .ebss23 .sbss .sbss23	*xxx*.zbss *xxx*.zbss23 *xxx*.bss *xxx*.tbss4 *xxx*.tbss5 *xxx*.tbss7 *xxx*.tbss8 *xxx*.ebss *xxx*.ebss23 *xxx*.sbss *xxx*.sbss23
Type const	const zconst zconst23	.const .zconst .zconst23	*xxx*.const *xxx*.zconst *xxx*.zconst23
Type text	text	.text	*xxx*.text
Clearing of specification	default	Clears all specifications, and restores the default section name.	

Note This is the actual section name when the section name of "xxx" is given.

Examples 1.

```
#pragma section r0_disp32   "mydata"
int i = 0;                      /*Allocated to "mydata.data"*/
int j;                          /*Allocated to "mydata.bss"*/

#pragma section gp_disp16   "mydata2"
int i2 = 1;                     /*Allocated to "mydata2.sdata"*/

#pragma section const       "myconst"
const int c2 = 0;               /*Allocated to "myconst.const"*/
int j2;                         /*Allocated to ".bss"*/
```

2.

```
#pragma section ep_disp4    "XXX"
extern  int     i;
void func()
{
        i = 5;
}
#pragma section r0_disp32   "OOO"
int i = 5;              /*Allocated to "XXX.tdata4"*/
                        /*When #pragma section is specified for the first*/
                        /*declaration, it takes priority*/
```

3.

```
#pragma section ep_disp4
int     i;
#pragma section ep_disp23
int     i;              /*Allocated to "tbss4"*/
                        /*When #pragma section is specified for the first*/
                        /*declaration, it takes priority*/
```

4.

```
<def.c>
#pragma section ep_disp4
extern  int     i;
#pragma section ep_disp4    "XXX"
int i = 5;                      /*Allocated to ".tdata4"*/
                                /*When #pragma section is specified for the*/
                                /*first declaration, it takes priority*/

<use.c>
#pragma section ep_disp4
extern  int     i;
void func()
{
        i = 5;                  /*No problems with access*/
}
```

5.

```
#pragma section ep_disp4    "XXX"
extern  int     i;
#pragma section ep_disp4     "OOO"
int     i = 5;                  /*Allocated to ".tdata4"*/
                                /*When #pragma section is specified for the*/
                                /*first declaration, it takes priority*/
```

6.

```
#pragma section r0_disp16   "myzdata"
#pragma section const       "myconst"   /*Specification of "myzdata" ends*/
                                        /*at this line*/
int     i = 0;                          /*No effect, because not .data const*/
const int       ci = 0;                 /*myconst.const*/
#pragma section r0_disp16   "myzadata"  /*Re-specify*/
int     j = 0;                          /*Becomes myzdata.zdata*/
const int       cj = 0;                 /*The myconst specification in the*/
                                        /*pragma immediately preceding the*/
                                        /*.const is erased, and it is*/
                                        /*placed in ".const".*/
```

7.

```
extern  int     i;

#pragma section ep_disp4
int     i;      /*Allocated to ".tdata4"*/
                /*Although this differs from the declaration side, even if*/
                /*this is accessed without #pragma section ep_disp23 in*/
                /*other translation units, access is correctly done in*/
                /*long-distance addressing mode (however, it is not*/
                /*efficient)*/
```

8.

```
#pragma section ep_disp23
#pragma section default
extern  int     i;

#pragma section ep_disp4
int     i;      /*Allocated to ".tdata4"*/
                /*#pragma section default, which restores the section name*/
                /*to the default name, is not regarded as a section*/
                /*specification*/
                /*The extern declaration is handled as a declaration*/
                /*without section specification*/
```

<2> Specifying "#pragma section *attribute-strings*"

Variables declared after the #pragma will be placed in the default section.

- Specifies placement of data in the default section name.
- The placement rules are the same as for "#pragma section *attribute-string* "*section-name*"", except for the fact that they are placed in the default section name.

Table 3-18. Section Relocation Attribute

Target	Attribute Strings	Default Section Name
Definition (type data)	r0_disp16 r0_disp23 r0_disp32 ep_auto ep_disp4 ep_disp5 ep_disp7 ep_disp8 ep_disp16 ep_disp23 gp_disp16 gp_disp23	.zdata .zdata23 .data Automatically selected from among .tdata4, .tdata5, .tdata7, and .tdata8 .tdata4 .tdata5 .tdata7 .tdata8 .edata .edata23 .sdata .sdata23
Declaration (type bss)	The compiler automatically determines variable definitions without an initial value to be of type bss. It is thus not a bss attribute string.	.zbss .zbss23 .bss .tbss4 .tbss5 .tbss7 .tbss8 .ebss .ebss23 .sbss .sbss23
Type const	const zconst zconst23	.const .zconst .zconst23
Type text	text	.text
Clearing of specification	default	Clears all specifications, and restores the default section name.

Example

```
#pragma section gp_disp16
int a = 1;                          /*Allocated to ".sdata"*/
int b;                              /*Allocated to ".sbss"*/
```

- -ep_auto produces the same behavior as ep_disp4, ep_disp5, ep_disp7, or ep_disp8 depending on the type of declaration.

Type of Declaration	Corresponding ep_disp*n*
unsigned char	ep_disp4
unsigned short	ep_disp5

Type of Declaration	Corresponding ep_disp*n*
signed char char _Bool	ep_disp7
signed short signed int unsigned int signed long unsigned long signed long long unsigned long long float double long double pointer enumerate type (when the size of the elements is that of the int type)	ep_disp8

Remarks 1. The ep_disp*n* for array-type variables depends on the type of the elements. In a multi-dimensional array (an array of arrays), however, the selected ep_disp*n* corresponds to the type of the elements stored in the array.

```
#pragma section ep_auto
char    c_ary[3][5] = {0};      /*.tdada7 (char)*/
char*   p_ary[3][5] = {0};      /*.tdata8 (pointer)*/
```

2. If a variable of the enumerate type is smaller than one of the int type due to the -Xenum_type option having been specified, the ep_disp*n* that corresponds to the given smaller type is selected.
3. Structures and unions are not allocated as any from among .tdata4, .tdata5, .tdata7, and .tdata8.

- Since ep_auto produces the same behavior as ep_disp4, ep_disp5, ep_disp7, or ep_disp8 depending on the type of declaration, ep_auto and the ep_disp*n* that produces the same behavior being specified for the declaration and definition of the same variable does not lead to an error. ep_auto and an ep_disp*n* that produces different behavior being specified for the declaration and definition of the same variable will lead to an error.

Examples 1.

```
#pragma section ep_auto
extern  unsigned char   ch;
#pragma section ep_disp4
unsigned char       ch; /*Allocated as .tdata4 with no errors or warnings*/
```

2.

```
#pragma section ep_auto
extern  unsigned char   ch;
#pragma section ep_disp7
unsigned char       ch; /*Allocated as .tdata4 with no errors or warnings*/
                        /*When #pragma section is specified for the first*/
                        /*declaration, it takes priority*/
```

<3> Specifying "#pragma section [*character-string*]"

This switches the section name output by the compiler.

The section name after switching from the default section name is as follows.

Target	Specifying	Default	After Switching
Program	#pragma section *xxx*	text	*xxx*.text
Constant		const	*xxx*.const
Initialized data		data	*xxx*.data
Uninitialized data		bss	*xxx*.bss

- If the string is omitted, all section names are set to the default.

Example

```
#pragma section abc
int a;                  /*a is allocated to the section abc.bss*/
const int d=1;          /*d is allocated to the section abc.const*/
void f(void)            /*f is allocated to the section abc.text*/
{
        a = d;
}

#pragma section
int b;                  /*b is allocated to the section .bss*/
void g(void)            /*g is allocated to the section .text*/
{
        b = d;
}

#pragma section 123
int c;                  /*c is allocated to the section _123.bss*/
void h(void)            /*h is allocated to the section _123.text*/
{
        c = d;
}
```

(2) Describing assembler instruction

With the CC-RH, assembler instruction can be described in the functions of a C source program.

(a) #pragma directives

One of the #pragma directives to embed assembler instructions is #pragma inline_asm.
This treats the function itself as an assembler instruction only, and performs inline expansion at the call site.

Performs inline expansion on functions coded in assembly and declared with #pragma inline_asm.
The calling conventions for an inline function with embedded assembly are the same as for ordinary function calls.
Specifying (size = numerical value) does not affect the result of compilation.

Example

- C source

```
#pragma inline_asm      func_add
static int      func_add(int a, int b){
        add     r6, r7
        mov     r7, r10
}
void func(int *p){
        *p = func(10,20);
}
```

- Output codes

```
_func:
prepare r20, 0
mov     r6, r20
movea   0x0014, r0, r7
mov     10, r6
add     r6, r7
mov     r7, r10
```

(b) Notes for Use of #pragma inline_asm

- Specify #pragma inline_asm before the definition of the function body.
- Also generate external definitions of functions specified with #pragma inline_asm.
- If you use a register to guarantee the entrance and exit of an inline function with embedded assembly, you must save and restore this register at the beginning and end of the function.
- The compiler passes strings in #pragma inline_asm to the assembler as-is, without checking or modifying them.
- Only positive integer constants are specifiable for (size = numerical value). Specifying a floating-point number or value less than 0 will cause an error.
- If #pragma inline_asm is specified for a static function, then the function definition will be deleted after inline expansion.
- Assembly code is targeted by the preprocessor. Caution is therefore needed when using #define to define a macro with the same name as an instruction or register used in assembly language (e.g. "MOV" or "r5").

- Although it is possible to use comments starting with a hash ("#") in RH850 assembly language, if you use this comment, do not use # comments inside functions coded in assembly, because the preprocessor will interpret these as preprocessing directives.
- If you write a label in a function coded in assembly, labels with the same name will be created for each inline expansion.
  In this situation, use local labels coded in assembly. Although local labels have the same name in the assembly source, the assembler converts them to different names automatically.

(3) Inline expansion

The CC-RH allows inline expansion of each function. This section explains how to specify inline expansion.

(a) Inline Expansion

Inline expansion is used to expand the main body of a function at a location where the function is called. This decreases the overhead of function call and increases the possibility of optimization. As a result, the execution speed can be increased.
If inline expansion is executed, however, the object size increases.
Specify the function to be expanded inline using the #pragma inline directive.

```
#pragma inline [()]function-name[, function-name, ...][()]
```

Describe functions that are described in the C language. In the case of a function, "void func1() {}", specify "func1". Two or more function names can be specified with each delimited by "," (comma).

```
#pragma inline  func1, func2
void    func1() {...}
void    func2() {...}
void func(void) {
        func1();    /*function subject to inline expansion*/
        func2();    /*function subject to inline expansion*/
}
```

(b) Conditions of inline expansion

At least the following conditions must be satisfied for inline expansion of a function specified using the #pragma inline directive.
Inline expansion may not be executed even if the following conditions are satisfied, because of the internal processing of the CC-RH.

<1> A function that expands inline and a function that is expanded inline are described in the same file

A function that expands inline and a function that is expanded inline, i.e., a function call and a function definition must be in the same file. This means that a function described in another C source cannot be expanded inline. If it is specified that a function described in another C source is expanded inline, the CC-RH does not output a warning message and ignores the specification.

<2> The #pragma inline directive is described before function definition.

If the #pragma inline directive is described after function definition, the CC-RH outputs a warning message and ignores the specification. However, prototype declaration of the function may be described in any order. Here is an example.

Example

```
[Valid Inline Expansion Specification]
#pragma inline  func1, func2
void    func1();        /*prototype declaration*/
void    func2();        /*prototype declaration*/
void    func1() {...}   /*function definition*/
void    func2() {...}   /*function definition*/
```

```
[Invalid Inline Expansion Specification]
void    func1();        /*prototype declaration*/
void    func2();        /*prototype declaration*/
void    func1() {...}   /*function definition*/
void    func1() {...}   /*function definition*/
#pragma inline  func1, func2
```

<3> The number of arguments is the same between "call" and "definition" of the function to be expanded inline.

If the number of arguments is different between "call" and "definition" of the function to be expanded inline, the CC-RH ignores the specification.

<4> The types of return value and argument are the same between "call" and "definition" of the function to be expanded inline.

If the number of arguments is different between "call" and "definition" of the function to be expanded inline, the CC-RH ignores the specification. If the type of the argument is the integer type (including enum) or pointer-type, and in the same size, however, inline expansion is executed.

<5> The number of arguments of the function to be expanded inline is not variable.

If inline expansion is specified for a function with a variable arguments, the CC-RH outputs neither an error nor warning message and ignores the specification.

<6> Recursive function is not specified to be expanded inline.

If a recursive function that calls itself is specified for inline expansion, the CC-RH outputs neither an error nor warning message and ignores the specification. If two or more function calls are nested and if a code that calls itself exists, however, inline expansion may be executed.

<7> The addresses of formal parameters are not referenced from inside the function.

If you reference the address of a formal parameter from inside a function, then the inline expansion specification will be ignored, without outputting an error or warning message.

<8> does not make calls via the addresses of functions for inline expansion.

If you call a function for inline expansion via its address, then the inline expansion specification will be ignored, without outputting an error or warning message.

<9> An interrupt handler is not specified to be expanded inline.

A function specified by the #pragma interrupt is recognized as an interrupt handler. If inline expansion is specified for this function, the CC-RH outputs a warning message and ignores the specification.

<10> Interrupts are not disabled in a function by the #pragma block_interrupt directive.

#If inline expansion is specified for a function in which interrupts are declared by the #pragma block_interrupt directive to be disabled, the CC-RH outputs a warning message and ignores the specification.

<11> If #pragma inline_asm is specified, then a #pragma inline specification will be ignored.

If you specify inline expansion for a function coded in assembly using #pragma inline_asm, then a warning message will be output, and the #pragma inline specification will be ignored.

<12> If you specify -merge_files, then functions may be inlined even if they are not coded within the file.

(c) Functions ineligible for inline expansion

When using the -Oinline option, use #pragma noinline to prevent inline expansion of a specific function.

```
#pragma noinline  [(]function-name[, function-name, ...][)]
```

Specifying #pragma inline and #pragma noinline for the same function simultaneously within a single translation unit will cause an error.

(d) Examples of differences in inline expansion operation depending on option specification

Here are differences in inline expansion operation depending on whether the #pragma inline directive or an option is specified.

-Oinline=0	Inline expansion specification will be ignored, without outputting an error or warning message.
-Oinline=1	Inline expansion will be performed on functions specified for it.
-Oinline=2	Inline expansion will be performed on functions automatically, even if it is not specified. However, inline expansion will not be performed on functions specified as ineligible for inline expansion.
-Oinline=3	Inline expansion will be performed on functions automatically, even if it is not specified. However, inline expansion will not be performed on functions specified as ineligible for inline expansion.

(e) Sample inline expansion

Below is an example of inline expansion.

- C source

```
pragma inline  (func)
static int      func(int a, int b)
{
        return  (a+b)/2;
}
int     x;
main()
{
        x = func (10, 20);
}
```

- Sample expansion

```
int     x;
main()
{
        int     func_result;
{
        int     a_1 = 10, b_1 = 20;
        func_result = (a_1+b_1)/2;
}
        x = func_result;
}
```

(4) Controlling interrupt level

The CC-RH can manipulate the interrupts of the RH850 family as follows in a C source.

- By controlling interrupt level
- By enabling or disabling acknowledgment of maskable interrupts (by masking interrupts)

In other words, the interrupt control register can be manipulated.

(a) Controlling the interrupt priority level

For this purpose, the "__ set_il" function is used. Specify this function as follows to manipulate the interrupt priority level.

```
__set_il_rh(int interrupt-priority-level, void* address of interrupt control
register);
```

Integer values 1 to 16 can be specified as the interrupt priority level. With RH850, sixteen steps, from 0 to 15, can be specified as the interrupt priority level. To set the interrupt priority level to "5", therefore, specify the interrupt priority level as "6" by this function.

(b) Enable or disable acknowledgement of maskable interrupts (interrupt mask)

Specify the __ set_il function as follows to enable or disable acknowledgment of a maskable interrupt.

```
__set_il_rh(int enables/disables maskable interrupt, void* address of interrupt
control register);
```

Integer values -3 to 0 can be specified to enable or disable the maskable interrupt.

Set Value	Operation
0	Enables acknowledgement of maskable interrupt (unmasks interrupt).
-1	Disables acknowledgment of maskable interrupt (masks interrupt).
-2	To use direct branching (standard specification) as the interrupt vector method
-3	To use table lookup (extended specification) as the interrupt vector method

(5) Interrupt/Exception processing handler

The CC-RH can describe an "Interrupt handler" or "Exception handler" that is called if an interrupt or exception occurs. This section explains how to describe these handlers.

(a) Occurrence of interrupt/exception

If an interrupt or exception occurs in the RH850 family, the program jumps to a handler address corresponding to the interrupt or exception.
The arrangement of the handler addresses and the available interrupts vary depending on the device of the RH850. See the Relevant Device's User's Manual of each device for details.

How to describe interrupt servicing is explained specifically in "(c) Describing interrupt/exception handler".

(b) Processing necessary in case of interrupt/exception

If an interrupt/exception occurs while a function is being executed, interrupt/exception processing must be immediately executed. When the interrupt/exception processing is completed, execution must return to the function that was interrupted.
Therefore, the register information at that time must be saved when an interrupt/exception occurs, and the register information must be restored when interrupt/exception processing is complete.

(c) Describing interrupt/exception handler

The format in which an interrupt/exception handler is described does not differ from ordinary C functions, but the functions described in C must be recognized as an interrupt/exception handler by the CC-RH. With the CC-RH, an interrupt/exception handler is specified using the #pragma interrupt directive.

```
#pragma interrupt   [()]Function-name[(interrupt specification [, interrupt
specification]...)] [,...] [()]
```

Describe functions that are described in the C language. In the case of a function, "void func1() {}", specify "func1".
Always give interrupt functions a return type of void.
The function exit code of an interrupt function is different from that of an ordinary function. You must therefore not call them in the same way as ordinary functions.

- Define an interrupt function
  You can define an interrupt function with either no parameters or one parameter.

Examples 1. Using no parameters

```
void i_func(void)
{
        :
}
```

2. Using one parameter

```
void i_func(unsigned long dummy)
{
        :
}
```

- *interrupt specification*

The following *interrupt specification* can be specified.

enable=	Specifies whether multiplex interrupts are enabled. This can be set to true, false, or manual. - true Output ei/di. Outputs code to save or restore eipc/eipsw. - false (default) Does not output ei/di. Does not output code to save or restore eipc/eipsw. - manual Does not output ei/di. Outputs code to save or restore eipc/eipsw.
priority= channel=	You can only specify one of either "priority" or "channel", but not both (writing both will cause a compilation error). - priority= Specifies the exception trigger. You can write only one of the following tokens. SYSERR/HVTRAP/FETRAP/TRAP0/TRAP1/RIE/FPP/FPI/UCPOP/MIP/MDP/ITLBE/ DTLBE/PIE/MAE/FENMI/FEINT/EIINT_priorityX (X is 0 -15) - channel= Specifies the interrupt channel. Select this if you are using the extended specification for interrupts. Generates code determining the EI compiler to be used. If you did not specify either "priority" or "channel", it will determine the EIINT.
fpu=	Specifies saving and restoration of fpepc/fpsr in the fpu context. This can be set to true, false, or auto. - true Saves and restores fpepc/fpsr. - false Does not save or restore fpepc/fpsr. - auto (default) Interpreted as true when the -Xfloat option is specified. Interpreted as false when -Xfloat=soft is specified.
callt=	Specifies saving/restoration of ctpc/ctpsw in the callt context. This can be set to true, false. - true (default) Saves and restore ctpc/ctpsw. - false Does not save or restore ctpc/ctpsw.

If you write an interrupt specification, you must include a term to the right of the equals sign ("=").
For example, writing only "enable=" will cause a compilation error. The default interrupt specification signifies the behavior when individual interrupt specifications are not written.

- Output code for EI level exception

The compiler inserts the following instructions at the entrance and exit of an EI level exception interrupt function. EIINT and FPI are some of the main corresponding items.
However, this is not inserted into all interrupt functions. Necessary processing is output in accordance with user-defined #pragma statements, compiler options, etc.

- [Entrance code of interrupt functions]
  (1) Allocates stack area for saving context
  (2) Saves Caller-Save register used in interrupt function
  (3) Saves EIPC and EIPSW
  (4) If the function has a formal parameter, set EIIC to R6
  (5) Enables multiplex interrupts
  (6) Saves WCTPC and CTPSW
  (7) Saves WFPEPC and FPSR

- [Exit code of interrupt functions]
  (8) Sets imprecise interrupt standby
  (9) Restorse FPEPC and FPSR
  (10) Restores CTPC and CTPSW
  (11) Disables multiplex interrupts
  (12) Restores EIPC and EIPSW
  (13) Restores Caller-Save register used in interrupt function
  (14) Frees stack area for saving context
  (15) eiret

Below is a specific example of the output code. Numbers (1) to (15) in the code correspond to the numbered actions above.
Note that the instructions in the output code will not necessarily be identical to this example. The instructions, general-purpose registers, and other details may differ from this example.

Examples 1. Sample1: output of EI level exception

```
#pragma interrupt func1(enable=true, callt=true, fpu=true)
void func1(unsigned long eiic)
{
        User-coded processing;
}
```

```
_func1:
    movea   -0x00000038, r3, r3 ; (1)
    st23.dw r6, 0x00000030[r3]  ; (2)
    stsr    0, r6               ; (3)
    stsr    1, r7               ; (3)
    st23.dw r6, 0x00000028[r3]  ; (3)
    stsr    13, r6              ; (4)
    ei                          ; (5)
    st23.dw r4, 0x00000020[r3]  ; (2)
    st23.dw r8, 0x00000018[r3]  ; (2)
    st23.dw r10, 0x00000010[r3] ; (2)
    stsr    16, r8              ; (6)
    stsr    17, r9              ; (6)
    st23.dw r8, 0x00000008[r3]  ; (6)
    stsr    7, r8               ; (7)
    stsr    6, r9               ; (7)
    st23.dw r8, 0x00000000[r3]  ; (7)
    prepare ....                ; Saves Callee-Save register
        :                       ; User-coded processing
    dispose ....                ; Restores Callee-Save register
    synce                       ; (8)
    ld23.dw 0x00000000[r3], r8  ; (9)
    ldsr    r9, 6               ; (9)
    ldsr    r8, 7               ; (9)
    ld23.dw 0x00000008[r3], r8  ; (10)
    ldsr    r9, 17              ; (10)
    ldsr    r8, 16              ; (10)
    ld23.dw 0x00000010[r3], r10 ; (13)
    ld23.dw 0x00000018[r3], r8  ; (13)
    ld23.dw 0x00000020[r3], r4  ; (13)
    di                          ; (11)
    ld23.dw 0x00000028[r3], r6  ; (12)
    ldsr    r7, 1               ; (12)
    ldsr    r6, 0               ; (12)
    ld23.dw 0x00000030[r3], r6  ; (13)
    movea   0x00000038, r3, r3  ; (14)
    eiret                       ; (15)
```

Compiler embeds entrance code into beginning of interrupt function

Interrupt processing coded by user

Compiler embeds exit code into end of interrupt function

2. Sample2: output of EI level exception
If there are no formal parameters, and interrupt multiplexing is set to manual (enable=manual)

```
#pragma interrupt func1(enable=true, callt=true, fpu=true)
void func1(unsigned long eiic)
 {
        User-coded processing;
}
```

```
_func1:
    movea   -0x00000038, r3, r3 ; (1)
    st23.dw r6, 0x00000030[r3]  ; (2)
    stsr    0, r6               ; (3)
    stsr    1, r7               ; (3)
    st23.dw r6, 0x00000028[r3]  ; (3)
    st23.dw r4, 0x00000020[r3]  ; (2)
    st23.dw r8, 0x00000018[r3]  ; (2)
    st23.dw r10, 0x00000010[r3] ; (2)
    stsr    16, r8              ; (6)
    stsr    17, r9              ; (6)
    st23.dw r8, 0x00000008[r3]  ; (6)
    stsr    7, r8               ; (7)
    stsr    6, r9               ; (7)
    st23.dw r8, 0x00000000[r3]  ; (7)
    prepare ....                ; Saves Callee-Save register
        :                       ; User-coded processing
    dispose ....                ; Restores Callee-Save register
    ld23.dw 0x00000000[r3], r8  ; (9)
    ldsr    r9, 6               ; (9)
    ldsr    r8, 7               ; (9)
    ld23.dw 0x00000008[r3], r8  ; (10)
    ldsr    r9, 17              ; (10)
    ldsr    r8, 16              ; (10)
    ld23.dw 0x00000010[r3], r10 ; (13)
    ld23.dw 0x00000018[r3], r8  ; (13)
    ld23.dw 0x00000020[r3], r4  ; (13)
    ld23.dw 0x00000028[r3], r6  ; (12)
    ldsr    r7, 1               ; (12)
    ldsr    r6, 0               ; (12)
    ld23.dw 0x00000030[r3], r6  ; (13)
    movea   0x00000038, r3, r3  ; (14)
    eiret                       ; (15)
```

Compiler embeds entrance code into beginning of interrupt function

Interrupt processing coded by user

Compiler embeds exit code into end of interrupt function

- Output code for FE level exception

The compiler inserts the following instructions at the entrance and exit of an FE level exception interrupt function. FEINT and PIE are some of the main corresponding items.
However, this is not inserted into all interrupt functions. Necessary processing is output in accordance with user-defined #pragma statements, compiler options, etc.

- [Entrance code of interrupt functions]
  (1) Allocates stack area for saving context
  (2) Saves all Caller-Save register used in interrupt function
  (3) If the function has a formal parameter, sets FEIC to R6
  (4) Saves CTPC and CTPSW
  (5) Saves FPEPC and FPSR

- [Exit code of interrupt functions]
  (6) Restores FPEPC and FPSR
  (7) Restores CTPC and CTPSW
  (8) Restores all Caller-Save register used in interrupt function
  (9) Frees stack area for saving context
  (10) feret

Below is a specific example of the output code. Numbers (1) to (10) in the code correspond to the numbered actions above.
Note that the instructions in the output code will not necessarily be identical to this example. The instructions, general-purpose registers, and other details may differ from this example.

Example Sample output of FE level exception

```
#pragma interrupt func1(priority=feint, callt=true, fpu=true)
void func1(unsigned long feic)
{
        User-coded processing;
}
```

```
_func1:
    movea   -0x00000030, r3, r3 ; (1)
    st23.dw r4, 0x00000028[r3]  ; (2)
    st23.dw r6, 0x00000020[r3]  ; (2)
    st23.dw r8, 0x00000018[r3]  ; (2)
    st23.dw r10, 0x00000010[r3] ; (2)
    stsr    14, r6              ; (3)
    stsr    16, r8              ; (4)
    stsr    17, r9              ; (4)
    st23.dw r8, 0x00000008[r3]  ; (4)
    stsr    7, r8               ; (5)
    stsr    6, r9               ; (5)
    st23.dw r8, 0x00000000[r3]  ; (5)
    prepare ....                ; Saves Callee-Save registe
        :                       ; User-coded processing
    dispose ....                ; Restores Callee-Save register
    ld23.dw 0x00000000[r3], r8  ; (6)
    ldsr    r9, 6               ; (6)
    ldsr    r8, 7               ; (6)
    ld23.dw 0x00000008[r3], r8  ; (7)
    ldsr    r9, 17              ; (7)
    ldsr    r8, 16              ; (7)
    ld23.dw 0x00000010[r3], r10 ; (8)
    ld23.dw 0x00000018[r3], r8  ; (8)
    ld23.dw 0x00000020[r3], r6  ; (8)
    ld23.dw 0x00000028[r3], r4  ; (8)
    movea   0x00000030, r3, r3  ; (9)
    feret                       ; (10)
```

Compiler embeds entrance code into beginning of FEINT

FEINT processing coded by user

Compiler embeds exit code into end of FEIN

- Output code for FE level exception (cannot recover/restore)

  The compiler inserts the following instructions at the entrance and exit of an FE level exception (cannot recover/restore) interrupt function. FENMI and SYSERR are some of the main corresponding items.

  - [Entrance code of interrupt functions]

    (1) If the function has a formal parameter, sets FEIC to R6

    Nothing is output if the function does not have any parameters.

  - [Exit code of interrupt functions]

    None

Remark No saving or restoration of context is output.
Code the save and restore the Callee-Save register is also not output.

Below is a specific example of the output code. Numbers (1) in the code correspond to the numbered actions above.

Example Sample output of FE level exception (cannot recover/restore)

```
#pragma interrupt func1(priority=fenmi)
void func1(unsigned long feic)
{
        User-coded processing;
}
```

```
_func1:
    stsr    14, r6                  ; (1)
        :
        :                           ; User-coded processing
        :
```

Compiler embeds entrance code into beginning of FENMI

FENMI processing coded by user

No code is output at the end

(d) Notes on describing interrupt/exception handler

- A function specified as an interrupt/exception handler cannot be expanded inline. The #pragma inline directive is ignored even if specified.

(6) Disabling or enabling maskable interrupts

The CC-RH can disable the maskable interrupts in a C source.
This can be done in the following two ways.

- Locally disabling interrupt in function
- Disabling interrupts in entire function

(a) Locally disabling interrupt in function

The "di instruction" and "ei instruction" of the assembler instruction can be used to disable an interrupt locally in a function described in C language. However, the CC-RH has functions that can control the interrupts in a C language source.

Table 3-19. Interrupt Control Function

Interrupt Control Function	Operation	Processing by CC-RH
__DI	Disables the acceptance of all maskable interrupts.	Generates di instruction.
__EI	Enables the acceptance of all maskable interrupts.	Generates ei instruction.

Example How to use the __DI and __EI functions and the codes to be output are shown below.

- C source

```
void func1(void) {
          :
        __DI();
        /*Describe processing to be performed with interrupt disabled.*/
        __EI();
          :
}
```

- Output codes

```
_func1:
        -- prologue code
          :
        di
        -- processing to be performed with interrupt disabled
        ei
          :
        -- epilogue code
        jmp     [lp]
```

(b) Disabling interrupts in entire function

The CC-RH has a "#pragma block_interrupt" directive that disables the interrupts of an entire function. This directive is described as follows.

```
#pragma block_interrupt [()function-name[])]
```

Describe functions that are described in the C language. In the case of a function, "void func1() {}", specify "func1".

The interrupt to the function specified by "function-name" above is disabled. As explained in "(a) Locally disabling interrupt in function", __ DI()" can be described at the beginning of a function and "__ EI()", at the end. In this case, however, an interrupt to the prologue code and epilogue code output by the CC-RH cannot be disabled or enabled, and therefore, interrupts in the entire function cannot be disabled.

Using the #pragma block_interrupt directive, interrupts are disabled immediately before execution of the prologue code, and enabled immediately after execution of the epilogue code. As a result, interrupts in the entire function can be disabled.

Example How to use the #pragma block_interrupt directive and the code that is output are shown below.

- C source

```
#pragma block_interrupt func1
void func1(void) {
          :
        /*Describe processing to be performed with interrupt disabled.*/
          :
}
```

- Output codes

```
_func1:
        di
        -- prologue code
          :
        -- processing to be performed with interrupt disabled
          :
        -- epilogue code
        ei
        jmp     [lp]
```

(c) Notes on disabling interrupts in entire function

Note the following points when disabling interrupts in an entire function.

- If an interrupt handler and a #pragma block_interrupt directive are specified for the same interrupt, the interrupt handler takes precedence, and the setting of disabling interrupts is ignored.
- If the following functions are called in a function in which an interrupt is disabled, the interrupt is enabled when execution has returned from the call.
- Function specified by #pragma block_interrupt.
- Function that disables interrupt at the beginning and enables interrupt at the end.
- Describe the #pragma block_interrupt directive before the function definition in the same file; otherwise an error occurs during compilation.
- However, the order of prototype declaration of a function is not affected.
- Neither #pragma inline nor inline expansion can be specified by an optimization option for the function specified by a #pragma block_interrupt directive. The inline expansion specification is ignored.
- A code that manipulates the ep flag (that indicates exception processing is in progress) in the program status word (PSW) is not output even if #pragma block_interrupt is specified.

(7) Embedded functions

In the CC-RH, some of the assembler instructions can be described in C source as "Embedded Functions". However, it is not described "as assembler instruction", but as a function format set in the CC-RH.

If a parameter is specified whose type cannot be implicitly converted to that of the parameter of the embedded function, then an warning is output, and it is treated as an embedded function.

A error is also output if a register number that does not exist in the hardware is specified for ldsr()/stsr().

The instructions that can be described as functions are as follows.

Table 3-20. Assembler Instruction

Assembler Instruction	Function	Embedded Function
di	Interrupt control	void __DI(void);
ei		void __EI(void);

-	Interrupt-priority-level control	int NUM;
		void* ADDR[Note 1];
		void __set_il_rh(NUM, ADDR);
		
		- NUM : 1 - 16
		movhi highw1(ADDR), r0, rX
		ld.b loww(ADDR)[rX], rY
		andi 0x00F0, rY, rY
		ori (Priority - 1), rY, rY
		st.b loww(ADDR)[rX]
		- NUM : 0
		movhi highw1(ADDR), r0, rX
		clr1 7, loww(ADDR)[rX]
		- NUM : -1
		movhi highw1(ADDR), r0, rX
		set1 7, loww(ADDR)[rX]
		- NUM : -2
		movhi highw1(ADDR), r0, rX
		clr1 6, loww(ADDR)[rX]
		- NUM : -3
		movhi highw1(ADDR), r0, rX
		set1 6, loww(ADDR)[rX]
		- NUM : No greater than 4 and no less than 17
		Out-of-range error

nop	No operation	void __nop(void);
halt	Stops the processor	void __halt(void);
satadd	Saturated addition	long a, b; long __satadd(a, b);
satsub	Saturated subtraction	long a, b; long __satsub(a, b);
bsh	Halfword data byte swap	long a; long __bsh(a);
bsw	Word data byte swap	long a; long __bsw(a);
hsw	Word data halfword swap	long a; long __hsw(a);
mul	Instruction that assigns higher 32 bits of multiplication result to variable	long a, b; long __mul32(a, b);

Assembler Instruction	Function	Embedded Function
mulu	Instruction that assigns higher 32 bits of unsigned multiplication result to variable	unsigned long a, b; unsigned long __mul32u(a, b);
sch0l	Bit (0) search from MSB side	long a; long __sch0l(a);
sch0r	Bit (0) search from LSB side	long a; long __sch0r(a);
sch1l	Bit (1) search from MSB side	long a; long __sch1l(a);
sch1r	Bit (1) search from LSB side	long a; long __sch1r(a);
ldsr	Loads to system register	long regID; unsigned long a; void __ldsr(regID[Note 2], a);
ldsr	Loads to system register	long regID; long selID; unsigned long a; void __ldsr_rh(regID[Note 2], selID[Note 2], a);
stsr	Stores contents of system register	long regID; unsigned long __stsr(regID[Note 2]);
stsr	Stores contents of system register	long regID; long selID; unsigned long __stsr_rh(regID[Note 2], selID[Note 2]);
caxi	Compare and Exchange	long *a; long b, c; long __caxi(a, b, c);
clr1	Bit clear	unsigned char *a; int bit; void __clr1(a, bit);
set1	Bit set	unsigned char *a; int bit; void __set1(a, bit);
not1	Bit not	unsigned char *a; int bit; void __not1(a, bit);
ldl.w[Note 3]	Atomic load.	long *a; long __ldlw(a);
stc.w[Note 3]	Store	long *a; long b; void __stcw(a, b);
synce	Exception synchronization	void __synce(void);

Assembler Instruction	Function	Embedded Function
synce	Instruction pipeline synchronization	void __synci(void);
syncm	Memory synchronization	void __syncm(void);
syncp	Pipeline synchronization	void __syncp(void);

Notes 1. For ADDR, specify the address of the interrupt control register.
2. Specified the system register number (0 to 31) in regID and 0 to 7 in selID.
3. A warning is output when the -Xcpu=g3k option is used.

Caution Even if a function is defined with the same name as an embedded function, it cannot be used. If an att isempt made to call such a function, processing for the embedded function provided by the compiler takes precedence.

(8) Structure type packing

In the CC-RH, the alignment of structure members can be specified at the C language level. This function is equivalent to the -Xpack option, however, the structure type packing directive can be used to specify the alignment value in any location in the C source.

Caution The data area can be reduced by packing a structure type, but the program size increases and the execution speed is degraded.

(a) Format of structure type packing

The structure type packing function is specified in the following format.

```
#pragma pack [()[1|2|4][)]
```

#pragma pack changes to an alignment value of the structure member upon the occurrence of this directive. The numeric value is called the packing value and the specifiable numeric values are 1, 2, 4. When the numeric value is not specified, the setting is the default alignment.Since this directive becomes valid upon occurrence, several directives can be described in the C source.

Example

```
#pragma pack 1  /*structure member aligned using 1-byte alignment*/
struct  TAG {
        char    c;
        int     i;
        short   s;
};
```

(b) Rules of structure type packing

The structure members are aligned in a form that satisfies the condition whereby members are aligned according to whichever is the smaller value: the structure type packing value or the member's alignment value.
For example, if the structure type packing value is 2 and member type is int type, the structure members are aligned in 2-byte alignment.

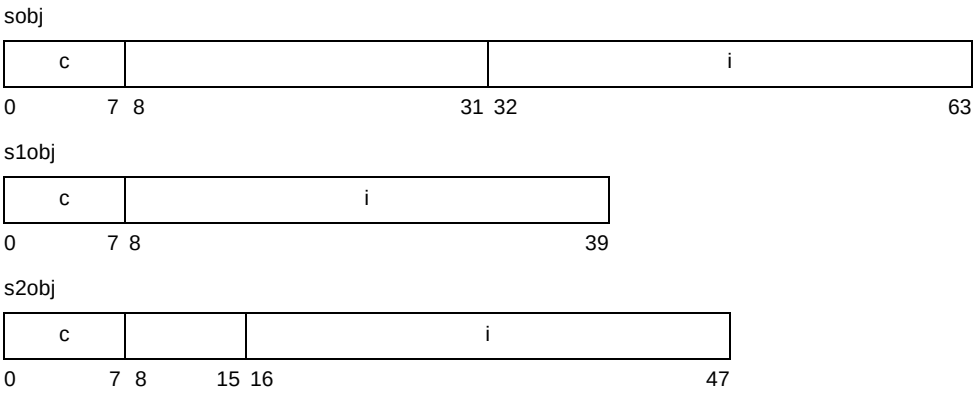
Example

```
struct  S {
        char    c;  /*satisfies 1-byte alignment condition*/
        int     i;  /*satisfies 4-byte alignment condition*/
};

#pragma pack 1
struct  S1 {
        char    c;  /*satisfies 1-byte alignment condition*/
        int     i;  /*satisfies 1-byte alignment condition*/
};

#pragma pack 2
struct  S2 {
        char    c;  /*satisfies 1-byte alignment condition*/
        int     i;  /*satisfies 2-byte alignment condition*/
};

struct  S   sobj;   /*size of 8 bytes*/
struct  S1  s1obj;  /*size of 5 bytes*/
struct  S2  s2obj;  /*size of 6 bytes*/
```



(c) Union

A union is treated as subject to packing and is handled in the same manner as structure type packing.

Examples 1.

```
union   U {
        char c;
        int i;
};

#pragma pack 1
union   U1 {
        char c;
        int i;
};

#pragma pack 2
union   U2 {
        char c;
        int i;
};

union   U   uobj;   /*size of 4 bytes*/
union   U1  u1obj;  /*size of 4 bytes*/
union   U2  u2obj;  /*size of 4 bytes*/
```

2.

```
union   U {
        int i:7;
};

#pragma pack 1
union   U1 {
        int i:7;
};

#pragma pack 2
union   U2 {
        int i:7;
};

union   U   uobj;   /*size of 4 bytes*/
union   U1  u1obj;  /*size of 1 byte*/
union   U2  u2obj;  /*size of 2 bytes*/
```

(d) Bit field

Data is allocated to the area of the bit field element as follows.

<1> When the structure type packing value is equal to or larger than the alignment condition value of the member type

Data is allocated in the same manner as when the structure type packing function is not used. That is, if the data is allocated consecutively and the resulting area exceeds the boundary that satisfies the alignment condition of the element type, data is allocated from the area satisfying the alignment condition.

<2> When the structure type packing value is smaller than the alignment condition value of the element type

- If data is allocated consecutively and results in the number of bytes including the area becoming larger than the element type

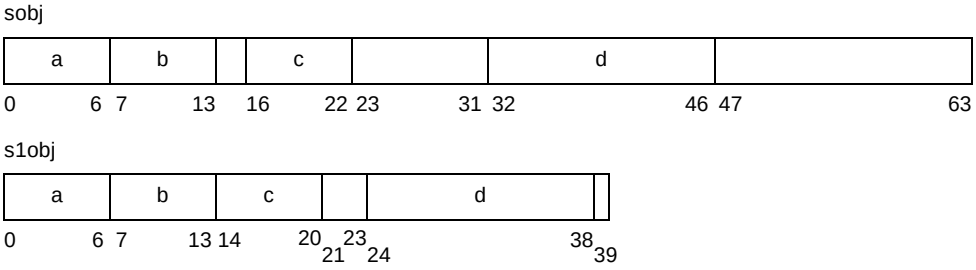
  The data is allocated in a form that satisfies the alignment condition of the structure type packing value.
- Other conditions

  The data is allocated consecutively.

Example

```
struct  S {
        short   a:7;    /*0 to 6th bit*/
        short   b:7;    /*7 to 13th bit*/
        short   c:7;    /*16 to 22nd bit (aligned to 2-byte boundary)*/
        short   d:15;   /*32 to 46th bit (aligned to 2-byte boundary)*/
} sobj;

#pragma pack 1
struct  S1 {
        short   a:7;    /*0 to 6th bit*/
        short   b:7;    /*7 to 13th bit*/
        short   c:7;    /*14 to 20th bit*/
        short   d:15;   /*24 to 38th bit  (aligned to byte boundary)*/
} s1obj;
```



(e) Alignment condition of top structure object

The alignment condition of the top structure object is the same as when the structure packing function is not used.

(f) Size of structure objects

Perform packing so that the size of structure objects becomes a multiple value of whichever is the smaller value: the structure alignment condition value or the structure packing value. The alignment condition of the top structure object is the same as when the structure packing function is not used.

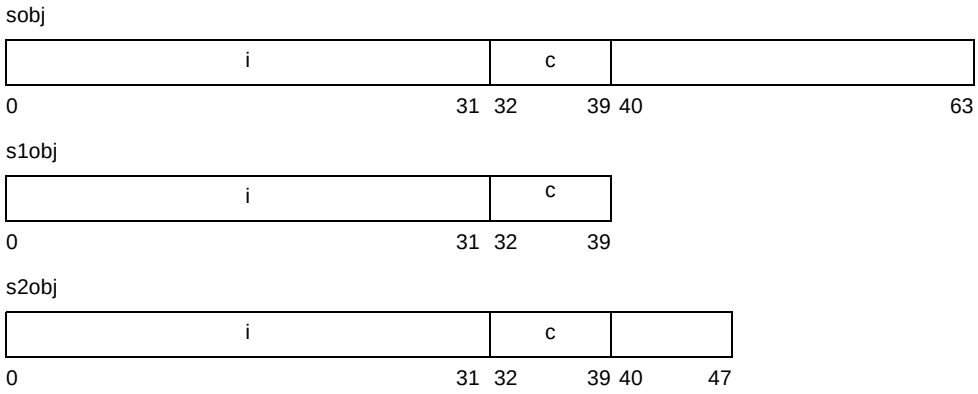
Examples 1.

```
struct  S {
        int     i;
        char    c;
};

#pragma pack 1
struct  S1 {
        int     i;
        char    c;
};

#pragma pack 2
struct  S2 {
        int     i;
        char    c;
};

struct  S   sobj;   /*size of 8 bytes*/
struct  S1  s1obj;  /*size of 5 bytes*/
struct  S2  s2obj;  /*size of 6 bytes*/
```



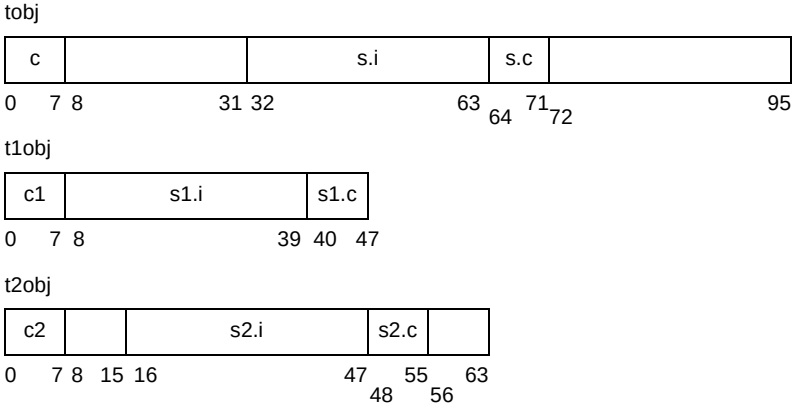
2.

```
struct  S {
        int     i;
        char    c;
};
struct  T {
        char    c;
        struct  S   s;
};

#pragma pack 1
struct  S1 {
        int     i;
        char    c;
};
struct  T1 {
        char    c;
        struct  S1  s1;
};

#pragma pack 2
struct  S2 {
        int     i;
        char    c;
};
struct  T2 {
        char    c;
        struct  S2  s2;
};

struct  T   tobj;   /*size of 12 bytes*/
struct  T1  t1obj;  /*size of 6 bytes*/
struct  T2  t2obj;  /*size of 8 bytes*/
```



(g) Size of structure array

The size of the structure object array is a value that is the sum of the number of elements multiplied to the size of structure object.

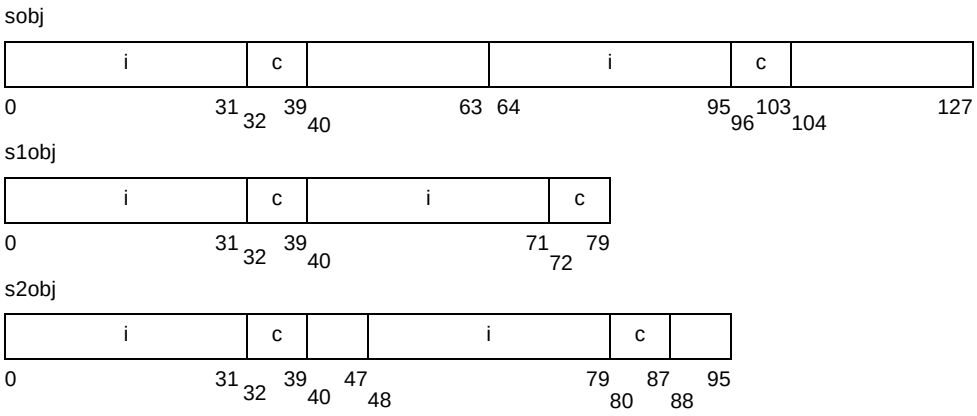
Example

```
struct  S {
        int     i;
        char    c;
};

#pragma pack 1
struct  S1 {
        int     i;
        char    c;
};

#pragma pack 2
struct  S2 {
        int     i;
        char    c;
};

struct  S   sobj[2];    /*size of 16 bytes*/
struct  S1  s1obj[2];   /*size of 10 bytes*/
struct  S2  s2obj[2];   /*size of 12 bytes*/
```

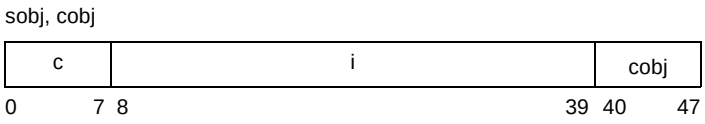


(h) Area between objects

For example, sobj.c, sobj.i, and cobj may be allocated consecutively without a gap in the following source program (the allocation order of sobj and cobj is not guaranteed).

Example

```
#pragma pack 1
struct  S {
        char    c;
        int     i;
} sobj;
char    cobj;
```



(i) Notes concerning structure packing function

<1> Specification of the -Xpack option and #pragma pack directive at the same time

If the -Xpack option is specified when structure packing is specified with the #pragma pack directive in the C source, the specified option value is applied to all the structures until the first #pragma pack directive appears. After this, the value of the #pragma pack directive is applied.
If you subsequently write #pragma pack (no value), then the value specified with this option is applied following that line.

Example When -Xpack=4 is specified

```
struct  S2 {...};   /*Packing value is specified as 4 in option.
                      -Xpack=4 option is valid: packing value is 4.*/
#pragma pack 2      /*Packing is specified as 2 in #pragma directive
struct  S1 {...};     pragma pack(2) is valid: packing value is 2.*/
#pragma pack        /*No specification of packing value with #pragma directive
struct  S2_2 {...};   -Xpack=4 option is valid: packing value is 4.*/
```

<2> Structure packing value and alignment value of members

Structure members are arranged so that the alignment conditions match the smaller of the structure's packing value and the members' alignment value. For example, if the structure's packing value is 2, and a member type is long, then it is ordered to meet the 2-byte alignment condition.

Example

```
struct S {
        char    c;      /*Meets 1-byte alignment condition*/
        long    i;      /*Meets 4-byte alignment condition*/
};

#pragma pack(1)
struct S1 {
        char    c;      /*Meets 1-byte alignment condition*/
        long    i;      /*Meets 1-byte alignment condition*/
};

#pragma pack(2)
struct S2 {
        char    c;      /*Meets 1-byte alignment condition*/
        long    i;      /*Meets 2-byte alignment condition*/
};

struct S        sobj;   /*Size 8 bytes*/
struct S1       s1obj;  /*Size 5 bytes*/
struct S2       s2obj;  /*Size 6 bytes*/
```

<3> Nested #pragma pack specification

Specify nested #pragma pack specifications for a structure as follows.
A warning is output for structure or union members with different alignment.
The alignment of members generating the warning will be in accordance with the #pragma pack statements in the source code.

Example

```
#pragma pack 1
struct ST1
{
        char    c;
#pragma pack 4
        struct ST4      //size=8, align=4 (Type is 4)
        {
            char    c;  //offset=1
            short   s;  //offset=3
            int     i;  //offset=5
        } st4;          //size=8, align=1 (1, because this is an ST1 member)
                        //Warning at location of member st4
        int i;
} st1;                  //size=13, align=1
```

(9) Bit field assignment

CC-RH can switch the order of a bit field.

(a) Format for specifying bit field assignment

Specify bit field assignment using the following format.

```
#pragma bit_order [{left|right}]
```

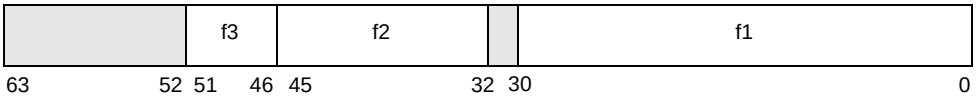
If left is specified, then members are assigned from the MSB; if right is specified, then they are assigned from the LSB.

Examples 1. The default is right.

```
#pragma bit_order right
struct {
        unsigned int    f1:30;
        int             f2:14;
        unsigned int    f3:6;
} flag;
```

The internal representation for the bit field in the above example is as follows.

Figure 3-11. Internal Representation of Bit Field

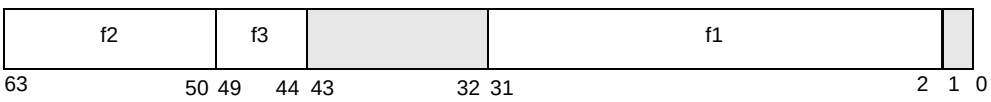


2.

```
#pragma bit_order left
struct {
        unsigned int    f1:30;
        int             f2:14;
        unsigned int    f3:6;
} flag;
```

The internal representation for the bit field in the above example is as follows.

Figure 3-12. Internal Representation of Bit Field

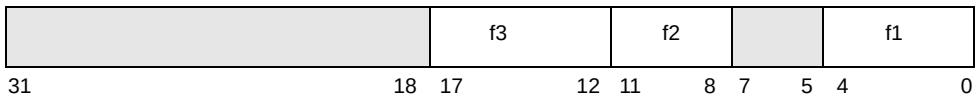


3.

```
#pragma bit_order right
struct {
    int             f1:5;
    char            f2:4;
    int             f3:6;
} flag;
```

The internal representation for the bit field in the above example is as follows.

Figure 3-13. Internal Representation of Bit Field

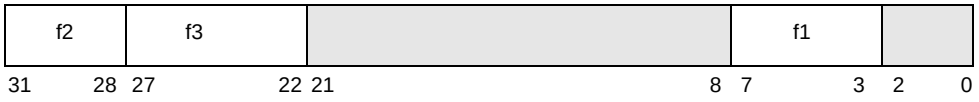


4.

```
#pragma bit_order left
struct {
    int             f1:5;
    char            f2:4;
    int             f3:6;
} flag;
```

The internal representation for the bit field in the above example is as follows.

Figure 3-14. Internal Representation of Bit Field



(10) Core number specification (for a multi-core device)

The core number specification function enables selection of data allocation area (the local memory in a specified core or the global memory shared by all cores) or selection of the core for function execution (a specified core or any core) when a multi-core device is used.
This function is specified by a combination of the #pragma directive described below and link options.

For example, to allocate variable x (assumed to be allocated to a data section) to the local memory for core number 1, specify as follows.

- Specify a pragma directive as follows before the first definition or declaration of variable x in the file:

```
#pragma pmodule pm1
```

This makes the compiler and assembler allocate variable x to section .data.pm1.

- Specify the following link option:

```
-start=.data.pm1/fe8f0000
```

This makes the linker allocate section .data.pm1 to the local memory for core number 1 (This example assumes 0xfe8f0000 as an address in the local memory for core number 1).

Specifying core numbers for variables or functions has the following merits.

- When a core number is added to each section name, the user can manage the correspondence between cores and variables or functions; that is, which variable is allocated to the local memory of which core and which function is executed in which core.
  This information can be viewed through CubeSuite+.
- As core numbers are added to all section names including the default section names, the user does not need to change the section names for every core.
- The compiler can check the correspondence between core numbers and data or functions (If a function that should be executed only in core 1 calls a function that should be executed only in core 2, the compiler can detect it as an error).

(a) Format for specifying core number

Specify a core number for a multi-core device in the following format.

```
#pragma pmodule pm-specification
```

This pragma directive is valid only when the -Xmulti_level option is specified. If the -Xmulti_level option is not specified, a warning is output and the core number specification is ignored.

The following table shows the available pm specification forms and the names of the corresponding allocated sections.
Only pm1 to pm255 or cmn can be written as pm specification. For a variable or a function with pm specification, a period (.) and the string used for pm specification is added at the end of the allocated section name.

-Xmulti_level Value	pm Specification Value	Meaning	Name of Allocation Section
1	None	Default (cmn) is specified.	***.cmn
	cmn	- For data Allocated to the global shared memory used in common for all cores. - For a function The function can be executed in any core	***.cmn
	pm1	Data or function for core 1	***.pm1
	:	:	:
	pm255	Data or function for core 255	***.pm255
0	A warning message is output and the core number specification is ignored.		*** (No string is added at the end of the section name.)

- If a pm specification other than cmn or pm1 to pm255 is written, a compilation error is generated.
- #pragma pmodule is applied to all static variable declarations, function declarations, and string literals[Note] that appear after the #pragma pmodule declaration line.

Note This directive is applied to all items allocated to the section; it is also applied to the string literals allocated to the const section.

- #The #pragma pmodule directive adds the string described above to both the default section names and user-specified section names.

Example .data -> .data.pm1
mydata.data -> mydata.data.pm1

- When the same variable or function declaration is specified multiple times within a single translation unit, if different #pragma pmodule specifications are written for them, the first specification is valid.

Example

```
#pragma pmodule pm1
extern  int     i;
#pragma pmodule pm2
int     i = 5;          //pm1 is valid
```

The following shows specification examples.
These examples assume that the -Xmulti_level=1 is specified.

Examples 1.

```
#pragma section r0_disp16
int     i;                      //.zbss.pm1
--------------------------------------------------------------------------------
#pragma pmodule pm2
int     i;                      //.bss.pm2
int     j = 5;                  //.data.pm2
const int       k = 10;         //.const.pm2
void func(void)                 //.text.pm2
{
        func2("abcde");         //"abcde" = .const.pm2
}
--------------------------------------------------------------------------------
#pragma pmodule pm2
#pragma section r0_disp16
int     i;                      //.zbss.pm2
--------------------------------------------------------------------------------
#pragma section r0_disp16
#pragma pmodule pm2
int     i;                      //.zbss.pm2
--------------------------------------------------------------------------------
#pragma pmodule pm2
#pragma pmodule pm3
#pragma section r0_disp16
int     i;                      //.zbss.pm3
#pragma pmodule pm1
int     j;                      //.zbss.pm1
```

2.

```
extern  int     i;
#pragma pmodule pm2
int     i;                      //.bss.pm2 (No warning)
```

3.

```
#pragma pmodule pm2
extern  int     i;
int     i;                      //.bss.pm2 (No warning)
```

4.

```
#pragma pmodule pm2
extern  int     i;
#pragma pmodule pm3
int     i;                          //.bss.pm2 (No warning)
```

3.2.6 Modification of C source

By using expanded function object with high efficiency can be created. However, as expanded function is adapted in RH850 family, C source needs to be modified so as to use in other than RH850 family.

Here, 2 methods are described for shifting to the CC-RH from other C compiler and shifting to C compiler from the CC-RH.

<From other C compiler to the CC-RH>

- #pragma[Note]

  C source needs to be modified, when C compiler supports the #pragma. Modification methods are examined according to the C compiler specifications.

- Expanded Specifications

  It should be modified when other C compilers are expanding the specifications such as adding keywords etc. Modified methods are examined according to the C compiler specifications.

Note #pragma is one of the pre-processing directives supported by ANSI. The character string next to #pragma is made to be recognized as directives to C compiler. If that directive does not supported by the compiler, #pragma directive is ignored and the compiler continues the process and ends normally.

<From the CC-RH to other C compiler>

- The CC-RH, either deletes key word or divides # fdef in order shift to other C compiler as key word has been added as expanded function.

Examples 1. Disable the keywords

```
#ifndef __CCRH__
#define interrupt       /*considered interrupt function as normal function*/
#endif
```

2. Change to other type

```
#ifdef  __v850e3v5__
#define _Bool char      /*change _Bool type variable to char type variable*/
#endif
```

CHAPTER 4 ASSEMBLY LANGUAGE SPECIFICATIONS

This chapter explains the assembly language specifications supported by the CC-RH assembler.

4.1 Description of Source

This section explains description of source, expressio, and operators.

4.1.1 Description

An assembly language statement consists of a "symbol", a "mnemonic", "operands", and a "comment".

```
[symbol][:Δ]        [mnemonic]      [operand], [operand]     ;[comment]
```

Separate labels by colons or one or more whitespace characters. Whether colons or spaces are used, however, depends on the instruction coded by the mnemonic.

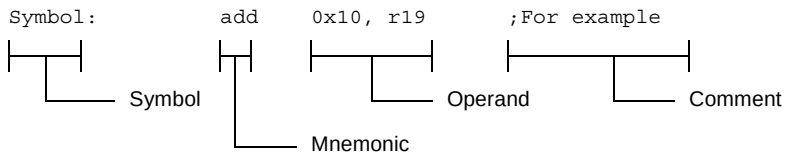
It is irrelevant whether blanks are inserted in the following location.

- Between the symbol name and colon
- Between the colon and mnemonic
- Before the second and subsequent operands
- Before semicolon that indicates the beginning of a comment

One or more blank is necessary in the following location.

- Between the mnemonic and the operand

Figure 4-1. Organization of Assembly Language Statement



One assembly language statement is described on one line. There is a line feed (return) at the end of the statement.

(1) Character set

The characters that can be used in a source program (assembly language) supported by the asembler are the following 3 types of characters.

- Language characters
- Character data
- Comment characters

(a) Language characters

These characters are used to code instructions in the source.

Table 4-1. Language Characters and Usage of Characters

Character	Usage
Numerals	Constitutes an identifier and constant
Lowercase letter (a-z)	Constitutes a mnemonic, identifier, and constant
Uppercase letter (A-Z)	Constitutes an identifier and constant
@	Constitutes an identifier and constant
_ (underscore)	Constitutes an identifier
.(period)	Constitutes an identifier and constant
~	Constitutes an identifier and constant
, (comma)	Delimits an operand
: (colon)	Delimits a label
; (semicolon)	Beginning of comment
*	Multiplication operator
/	Division operator
+	Positive sign and addition operator
- (hyphen)	Negative sign and subtraction operator
' (single quotation)	Character constant and symbol indicating a complete macro parameter
<	Relational operator
>	Relational operator
( )	Specifies an operation sequence
$	Symbol indicating the start of a control instruction equivalent to an assembler option Symbol specifying relative addressing gp offset reference of label
=	Relational operator
!	Beginning immediate addressing and negation operator
Δ (blank)	Field delimiter
~	Concatenation symbol (in macro body)
&	Logical product operator
#	Beginning indicates and comment
[ ]	Indirect indication symbol
"(double quotation)	Start and end of character string constant
%	ep offset referring of a label and remainder operator
<<	Left shift operator
>>	Right shift operator
|	Logical sum operator
^	Exclusive OR operator

(b) Character data

Character data refers to characters used to write character string constant, character constant, and the quote-enclosed operands of some control instructions.

Caution Character data can use all characters except 0x00 (including multibyte kanji, although the encoding depends on the OS). If 0x00 is encountered, an error occurs and all characters from the 0x00 to the closing single quote (') are ignored.

(c) Comment characters

Comment characters are used to write comments.

Caution Comment characters and character data have the same character set.

(2) Symbol

The symbol field is for symbols, which are names given to addresses and data objects. Symbols make programs easier to understand.

(a) Symbol types

Symbols can be classified as shown below, depending on their purpose and how they are defined.

Symbol Type	Purpose	Definition Method
Name	Used as names for addresses and data objects in source programs.	Write in the symbol field of a Symbol definition directive.
Label	Used as labels for addresses and data objects in source programs.	Write a symbol followed by a colon (:).
External reference name	Used to reference symbols defined by other source modules.	Write in the operand field of an external reference directive.
Section name	Used at link time.	Write in the symbol field of a section definition directive.
Macro name	Use to name macros in source programs.	Write in the symbol field of macro directive.

(b) Conventions of symbol description

Observe the following conventions when writing symbols.

- The characters which can be used in symbols are the alphanumeric characters and special characters (@, _, .).
  The first character in a symbol cannot be a digit (0 to 9). If you wish to specify a number as first character with a section name, enclose each file name with a double quotation (").
- The maximum number of characters for a symbol is 4,294,967,294 (=0xFFFFFFFE) (theoretical value). The actual number that can be used depends on the amount of memory, however.
- Reserved words cannot be used as symbols.
  See "4.5 Reserved Words" for a list of reserved words.
- The same symbol cannot be defined more than once.
  However, a symbol defined with the .set directive can be redefined with the .set directive.
- The assembler distinguishes between lowercase and uppercase characters.
- When a label is written in a symbol field, the colon (:) must appear immediately after the label name.

Example Correct symbols

```
CODE01   .cseg               ; "CODE01" is a section name.
VAR01    .set    0x10        ; "VAR01" is a name.
LAB01:   .dw     0           ; "LAB01" is a label.
```

Example Incorrect symbols

```
1ABC     .set    0x3         ; The first character is a digit.s
LAB      mov     1, r10      ; "LAB"is a label and must be separated from the mnemonic
                             ; field by a colon ( : ).
FLAG:    .set    0x10        ; The colon ( : ) is not needed for symbols.
```

Example A statement composed of a symbol only

```
ABCD:                        ; ABCD is defined as a label.
```

(c) Points to note about symbols

The assembler generates a name automatically when a section definition directive does not specify a name. These section names are listed below.

Duplicate section name definitions are errors.

Section Name	Directive	Relocation Attribute
.text	.cseg directive	TEXT
.const		CONST
.zconst		ZCONST
.zconst23		ZCONST23

Section Name	Directive	Relocation Attribute
.bss	.dseg directive	BSS
.data		DATA
.sbss		SBSS
.sdata		SDATA
.sbss23		SBSS23
.sdata23		SDATA23
.tdata		TDATA
.tbss4		TBSS4
.tdata4		TDATA4
.tbss5		TBSS5
.tdata5		TDATA5
.tbss7		TBSS7
.tdata7		TDATA7
.tbss8		TBSS8
.tdata8		TDATA8
.ebss		EBSS
.edata		EDATA
.ebss23		EBSS23
.edata23		EDATA23
.zbss		ZBSS
.zdata		ZDATA
.zbss23		ZBSS23
.zdata23		ZDATA23

(d) Symbol attributes

Every symbol and label has both a value and an attribute.
The value is the value of the defined data object, for example a numerical value, or the value of the address itself.
Macro names do not have values.
The following table lists symbol attributes.

Attribute Type	Classification	Value
BIT	- Symbols defined as bit values - Symbols defined with the EXTBIT directive	Decimal notation: -2147483648 to 2147483647 Hexadecimal notation: 0x80000000 to 0x7FFFFFFF (signed)
MACRO	Macro names defined with the Macro directive	These attribute types have no values.
FNUMBER	Symbols defined with the FLOAT directive (Single precision floating point)	1.40129846e-45 to 3.40282347e+38

Attribute Type	Classification	Value
DFNUMBER	Symbols defined with theDOUBLE directive (Double-precision floating point)	4.9406564584124654e-324 to 1.7976931348623157e+308

Example

```
BIT1    .set    0xFFE20.0   ; The symbol BIT1 has the BIT attribute and a value of 0xFFE20.0.
```

(3) Mnemonic field

Write instruction mnemonics, directives, and macro references in the mnemonic field.
If the instruction or directive or macro reference requires an operand or operands, the mnemonic field must be separated from the operand field with one or more blanks or tabs.
However, if the first operand begins with "#", "$","!", or "[", the statement will be assembled properly even if nothing exists between the mnemonic field and the first operand field.

Example Correct mnemonics

```
mov     1, r10
```

Example Incorrect mnemonics

```
mov1, r10       ; There is no blank between the mnemonic and operand fields.
mo v    1, r10  ; The mnemonic field contains a blank.
MOVE            ; This is an instruction that cannot be coded in the mnemonic field.
```

(4) Operand field

In the operand field, write operands (data) for the instructions, directives, or macro references that require them.
Some instructions and directives require no operands, while others require two or more.
When you provide two or more operands, delimit them with a comma (,).
The following types of data can appear in the operand field:

- Constants (numeric constants, character constants, character string constants)
- Register names
- Symbols
- Expressions

See the user's manual of the target device for the format and notational conventions of instruction set operands.
The following sections explain the types of data that can appear in the operand field.

(a) Constants

A constant is a fixed value or data item and is also referred to as immediate data.
There are numeric constants, character constants and character string constants.

- Numeric constants

  Integer constants can be written in binary, octal, decimal, or hexadecimal notation.
  Integer constants has a width of 32 bits. A negative value is expressed as a 2's complement. If an integer value that exceeds the range of the values that can be expressed by 32 bits is specified, the assembler

uses the value of the lower 32 bits of that integer value and continues processing (it does not output any message).

Type	Notation	Example
Binary	Append an "0b" suffix to the number.	0b1101
Octal	Append an "0" suffix to the number.	074
Decimal	Simply write the number.	128
Hexadecimal	Append an "0x" suffix to the number.	0xA6

Floating constants consist of the following elements. Specify the exponent and mantissa as decimal constants. Do not use (3), (4), or (5) if an exponent expression cannot be used.

(1) sign of mantissa part ("+" is optional)
(2) mantissa part
(3) 'e' or 'E' indicating the exponent part
(4) sign of exponent part ("+" is optional)
(5) exponent part

Example

```
123.4
-100.
10e-2
-100.2E+5
```

You can indicate that the number is a floating constant by appending "0f" or "0F" to the front of the mantissa.

Example

```
0f10
```

- Character constants

A character constant consists of a single character enclosed by a pair of single quotation marks (' ') and indicates the value of the enclosed character[Note].
If any of the escape sequences listed below is specified in " ' " and " ' ", the assembler regards the sequence as being a single character.

Example

```
'A'             ; 0x00000041
' '             ; 0x00000020 (1 blank)
```

Note If a character constant is specified, the assembler assumes that an integer having the value of that character constant is specified.

Table 4-2. Value and Meaning of Escape Sequence

Escape Sequence	Value	Meaning
\0	0x00	null character
\a	0x07	Alert
\b	0x08	Backspace
\f	0x0C	Form feed
\n	0x0A	Line feed
\r	0x0D	Carriage return
\t	0x09	Horizontal tab
\v	0x0B	Vertical tab
\\	0x5C	Back slash
\'	0x27	Single quotation marks
\"	0x22	Double quotation mark
\?	0x3F	Question mark
\ddd	0 to 0377	Octal number of up to 3 digits (0 < d < 7) Note
\xhh	0 to 0xFF	Hexadecimal number of up to 2 digits (0 < h < 9, a < h < f, or A < h < F)

Note If a value exceeding "\377" is sp value of the escape sequence becomes the lower 1 byte. Cannot be of value more than 0377. For example value of"\777"is 0377.

- Character string constants

A character-string constant is expressed by enclosing a string of characters from those shown in "(1) Character set", in a pair of single quotation marks (").

To include the single quote character in the string, write it twice in succession.

Example

```
"ab"            ; 0x6162
"A"             ; 0x41
" "             ; 0x20 (1 blank)
```

(b) Register names

The following registers can be named in the operand field:

- r0, zero, r1, r2, hp, r3, sp, r4, gp, r5, tp, r6, r7, r8, r9, r10, r11, r12, r13, r14, r15, r16, r17, r18, r19, r20, r21, r22, r23, r24, r25, r26, r27, r28, r29, r30, ep, r31, lp

r0 and zero (Zero register), r2 and hp (Handler stack pointer), r3 and sp (Stack pointer), r4 and gp (Global pointer), r5 and tp (Text pointer), r30 and ep (Element pointer), r31 and lp (Link pointer) shows the same register.

Remark For the ldsr and stsr instructions, the PSW, and system registers are specified by using the numbers. Further, in assembler, PC cannot be specified as an operand.

(c) Symbols

The assembler supports the use of symbols as the constituents of the absolute expressions or relative expressions that can be used to specify the operands of instructions and directives.

(d) Expressions

An expression is a combination of constants and symbols, by an operator.
Expressions can be specified as instruction operands wherever a numeric value can be specified.
See "4.1.2 Expressions and operators" for more information about expressions.

Example

```
TEN     .set    0x10
        mov     TEN - 0x05, r10
```

In this example, "TEN - 0x05" is an expression.
In this expression, a symbol and a numeric value are connected by the - (minus) operator. The value of the expression is 0x0B, so this expression could be rewritten as "mov 0x0B, r10".

(5) Comment

Describe comments in the comment field, after a semicolon (;).
The comment field continues from the semicolon to the new line code at the end of the line, or to the EOF code of the file.
Comments make it easier to understand and maintain programs.
Comments are not processed by the assembler, and are output verbatim to assembly lists.
Characters that can be described in the comment field are those shown in "(1) Character set".

4.1.2 Expressions and operators

An expression is a symbol, constant or location counter (indicated by $), an operator combined with one of the above, or a combination of operators.

Elements of an expression other than the operators are called terms, and are referred to as the 1st term, 2nd term, and so forth from left to right, in the order that they occur in the expression.

The assembler supports the operators shown in "Table 4-3. Operator Types". Operators have priority levels, which determine when they are applied in the calculation. The priority order is shown in "Table 4-4. Operator Precedence Levels".

The order of calculation can be changed by enclosing terms and operators in parentheses "( )".

Example

```
mov32   5 * (SYM + 1), r12
```

In the above example, "5 * (SYM+1)" is an expression. "5" is the 1st term, "SYM" is the 2nd term, and "1" is the 3rd term. The operators are "*", "+", and "( )".

Table 4-3. Operator Types

Operator Type	Operators
Arithmetic operators	+, -, *, /, %, +sign, -sign
Logic operators	!, &, |, ^
Relational operators	==, !=, >, >=, <, <=, &&, ||
Shift operators	>>, <<
Byte separation operators	HIGH, LOW
2-byte separation operators	HIGHW, LOWW, HIGHW1
Section aggregation operators	STARTOF, SIZEOF
Other operator	( )

The above operators can also be divided into unary operators and binary operators.

Unary operators	+sign, -sign, !, HIGH, LOW, HIGHW, LOWW, HIGHW1
Binary operators	+, -, *, /, %, &, |, ^, ==, =, >, >=, <, <=, >>, <<, &&, ||

Table 4-4. Operator Precedence Levels

Priority	Level	Operators
Higher	1	+sign, -sign, !
	2	*, /, %, >>, <<
	3	&, |, ^
	4	+, -
	5	==, !=, >, >=, <, <=
Lower	6	&&, ||

Expressions are operated according to the following rules.

- The order of operation is determined by the priority level of the operators.
  When two operators have the same priority level, operation proceeds from left to right, except in the case of unary operators, where it proceeds from right to left.
- Sub-expressions in parentheses "( )" are operated before sub-expressions outside parentheses.
- Expressions are operated using unsigned 32-bit values.
  If intermediate values overflow 32 bits, the overflow value is ignored.
- If the value of a constant exceeds 32 bits, an error occurs, and its value is calculated as 0.
- In division, the decimal fraction part is discarded.
  If the divisor is 0, an error occurs and the result is 0.
- Negative values are represented as two's complement.
- External reference symbols are evaluated as 0 at the time when the source is assembled (the evaluation value is determined at link time).

(1) Evaluation examples

Expression	Evaluation
2 + 4 * 5	22
(2 + 3) * 4	20
10/4	2
0 - 1	0xFFFFFFFF
-1 > 1	0x0 (False)
EXT[Note] + 1	1

Note EXT: External reference symbols

4.1.3 Arithmetic operators

The following arithmetic operators are available.

Operator	Overview
+	Addition of values of first and second terms.
-	Subtraction of value of first and second terms.
*	Multiplacation of value of first and second terms.
/	Divides the value of the 1st term of an expression by the value of its 2nd term and returns the integer part of the result.
%	Obtains the remainder in the result of dividing the value of the 1st term of an expression by the value of its 2nd term.
+sign	Returns the value of the term as it is.
-sign	The term value 2 complement is sought.

+

Addition of values of first and second terms.

[Function]

Returns the sum of the values of the 1st and 2nd terms of an expression.

[Application example]

```
        .org    0x100
START:  jr      START + 6       ; (1)
```

(1) The jr instruction causes a jump to "address assigned to START plus 6", namely, to address "0x100 + 0x6 = 0x106" when START label is 0x100.

-

Subtraction of value of first and second terms.

[Function]

Returns the result of subtraction of the 2nd-term value from the 1st-term value.

[Application example]

```
        .org    0x100
BACK:   jr      BACK - 6        ; (1)
```

(1) The jr instruction causes a jump to "address assigned to BACK minus 6", namely, to address "0x100 - 0x6 = 0xFA" when BACK label is 0x100.

*

Multiplacation of value of first and second terms.

[Function]

Returns the result of multiplication (product) between the values of the 1st and 2nd terms of an expression.

[Application example]

```
TEN     .set    0x10
        mov     TEN * 3, r10    ; (1)
```

(1) With the .set directive, the value "0x10" is defined in the symbol "TEN".
The expression "TEN * 3" is the same as "0x10 * 3" and returns the value "0x30".
Therefore, (1) in the above expression can also be described as: mov 0x30, r10.

/

Divides the value of the 1st term of an expression by the value of its 2nd term and returns the integer part of the result.

[Function]

Divides the value of the 1st term of an expression by the value of its 2nd term and returns the integer part of the result.

The decimal fraction part of the result will be truncated. If the divisor (2nd term) of a division operation is 0, an error occurs

[Application example]

```
mov     256 / 50, r10           ; (1)
```

(1) The result of the division "256 / 50" is 5 with remainder 6.
The operator returns the value "5" that is the integer part of the result of the division.
Therefore, (1) in the above expression can also be described as: mov 5, r10.

%

Obtains the remainder in the result of dividing the value of the 1st term of an expression by the value of its 2nd term.

[Function]

Obtains the remainder in the result of dividing the value of the 1st term of an expression by the value of its 2nd term.
An error occurs if the divisor (2nd term) is 0.

[Application example]

```
mov     256 % 50, r10   ; (1)
```

(1) The result of the division "256 / 50" is 5 with remainder 6.
The MOD operator returns the remainder 6.
Therefore, (1) in the above expression can also be described as: mov 6, r10.

+sign

Returns the value of the term as it is.

[Function]

Returns the value of the term of an expression without change.

[Application example]

```
FIVE    .set    +5      ; (1)
```

(1) The value "5" of the term is returned without change.
The value "5" is defined in symbol "FIVE" with the .set directive.

-sign

The term value 2 complement is sought.

[Function]

Returns the value of the term of an expression by the two's complement.

[Application example]

```
NO      .set    -1      ; (1)
```

(1) -1 becomes the two's complement of 1.
0000 0000 0000 0000 0000 0000 0000 0001 becomes:
1111 1111 1111 1111 1111 1111 1111 1111
Therefore, with the .set directive, the value "0xFFFFFFFF" is defined in the symbol "NO".

4.1.4 Logic operators

The following logic operators are available.

Operator	Overview
!	Obtains the logical negation (NOT) by each bit.
&	Obtains the logical AND operation for each bit of the first and second term values.
|	Obtains the logical OR operation for each bit of the first and second term values.
^	Obtains the exclusive OR operation for each bit of the first and second term values.

!

Obtains the logical negation by each bit.

[Function]

Negates the value of the term of an expression on a bit-by-bit basis and returns the result.

[Application example]

```
mov     !0x3, r10       ; (1)
```

(1) Logical negation is performed on "0x3" as follows:
0xFFFC is returned.
Therefore, (1) can also be described as: mov 0xFFFC, r10.

NOT)	0000	0000	0000	0000	0000	0000	0000	0011
	1111	1111	1111	1111	1111	1111	1111	1100

&

Obtains the logical AND operation for each bit of the first and second term values.

[Function]

Performs an AND (logical product) operation between the value of the 1st term of an expression and the value of its 2nd term on a bit-by-bit basis and returns the result.

[Application example]

```
mov     0x6FA & 0xF, r10        ; (1)
```

(1) AND operation is performed between the two values "0x6FA" and "0xF" as follows:
The result "0xA" is returned. Therefore, (1) in the above expression can also be described as:
mov 0xA, r10.

	0000	0000	0000	0000	0000	0110	1111	1010
&)	0000	0000	0000	0000	0000	0000	0000	1111
	0000	0000	0000	0000	0000	0000	0000	1010

Obtains the logical OR operation for each bit of the first and second term values.

[Function]

Performs an OR (Logical sum) operation between the value of the 1st term of an expression and the value of its 2nd term on a bit-by-bit basis and returns the result.

[Application example]

```
mov     0xA | 0b1101, r10       ; (1)
```

(1) OR operation is performed between the two values "0xA" and "0b1101" as follows:
The result "0xF" is returned.
Therefore, (1) in the above expression can also be described as: mov 0xF, r10.

	0000	0000	0000	0000	0000	0000	0000	1010
|	0000	0000	0000	0000	0000	0000	0000	1101
	0000	0000	0000	0000	0000	0000	0000	1111

^

Obtains the exclusive OR operation for each bit of the first and second term values.

[Function]

Performs an Exclusive-OR operation between the value of the 1st term of an expression and the value of its 2nd term on a bit-by-bit basis and returns the result.

[Application example]

```
mov32   0x9A ^ 0x9D, r12        ; (1)
```

(1) XOR operation is performed between the two values "0x9A" and "0x9D" as follows:
The result "0x7" is returned.
Therefore, (1) in the above expression can also be described as: mov32 0x7, r12.

	0000	0000	0000	0000	0000	0000	1001	1010
^)	0000	0000	0000	0000	0000	0000	1001	1101
	0000	0000	0000	0000	0000	0000	0000	0111

4.1.5 Relational operators

The following relational operators are available.

Operator	Overview
==	Compares whether values of first term and second term are equivalent.
!=	Compares whether values of first term and second term are not equivalent.
>	Compares whether value of first term is greater than value of the second.
>=	Compares whether value of first term is greater than or equivalent to the value of the second term.
<	Compares whether value of first term is smaller than value of the second.
<=	Compares whether value of first term is smaller than or equivalent to the value of the second term.
&&	Calculates the logical product of the logical value of the first and second operands.
||	Calculates the logical sum of the logical value of the first and second operands.

==

Compares whether values of first term and second term are equivalent.

[Function]

Returns ~0 (True) if the value of the 1st term of an expression is equal to the value of its 2nd term, and 0 (False) if both values are not equal.

!=

Compares whether values of first term and second term are not equivalent.

[Function]

Returns ~0 (True) if the value of the 1st term of an expression is not equal to the value of its 2nd term, and 0 (False) if both values are equal.

>

Compares whether value of first term is greater than value of the second.

[Function]

Returns ~0(True) if the value of the 1st term of an expression is greater than the value of its 2nd term, and 0 (False) if the value of the 1st term is equal to or less than the value of the 2nd term.

>=

Compares whether value of first term is greater than or equivalent to the value of the second term.

[Function]

Returns ~0 (True) if the value of the 1st term of an expression is greater than or equal to the value of its 2nd term, and 0 (False) if the value of the 1st term is less than the value of the 2nd term.

<

Compares whether value of first term is smaller than value of the second.

[Function]

Returns ~0 (True) if the value of the 1st term of an expression is less than the value of its 2nd term, and 0 (False) if the value of the 1st term is equal to or greater than the value of the 2nd term.

<=

Compares whether value of first term is smaller than or equivalent to the value of the second term.

[Function]

Returns ~0 (True) if the value of the 1st term of an expression is less than or equal to the value of its 2nd term, and 0 (False) if the value of the 1st term is greater than the value of the 2nd term.

&&

Calculates the logical product of the logical value of the first and second operands.

[Function]

Calculates the logical product of the logical value of the first and second operands.

Calculates the logical sum of the logical value of the first and second operands.

[Function]

Calculates the logical sum of the logical value of the first and second operands.

4.1.6 Shift operators

The following shift operators are available.

Operator	Overview
>>	Obtains only the right-shifted value of the first term which appears in the second term.
<<	Obtains only the left-shifted value of the first term which appears in the second term.

>>

Obtains only the right-shifted value of the first term which appears in the second term.

[Function]

Returns a value obtained by shifting the value of the 1st term of an expression to the right the number of bits specified by the value of the 2nd term.

The sign bit is not shifted.

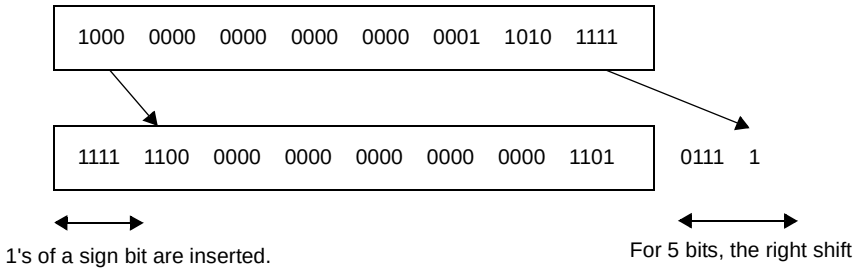
The sign bit is inserted in the high-order bits, the same number of times as the number of bits that were shifted.

If the number of shifted bits is 0, the value of the first term is returned as is. If the number of shifted bits exceeds 31, 0 is returned.

[Application example]

```
mov32   0x800001AF >> 5, r20     ; (1)
```

(1) The value "0x800001AF" is shifted 5 bits to the right, leaving the sign bit.
"0xFC00000D" is forwarded to r20.
Therefore, (1) in the above example can also be described as: mov32 0xFC00000D,r20.



<<

Obtains only the left-shifted value of the first term which appears in the second term.

[Function]

Returns a value obtained by shifting the value of the 1st term of an expression to the left the number of bits specified by the value of the 2nd term.

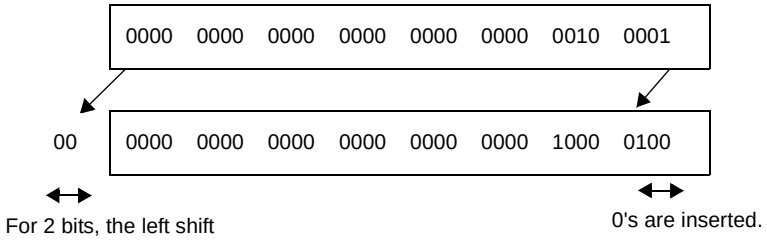
Zeros equivalent to the specified number of bits shifted move into the low-order bits.

If the number of shifted bits is 0, the value of the first term is returned as is. If the number of shifted bits exceeds 31, 0 is returned.

[Application example]

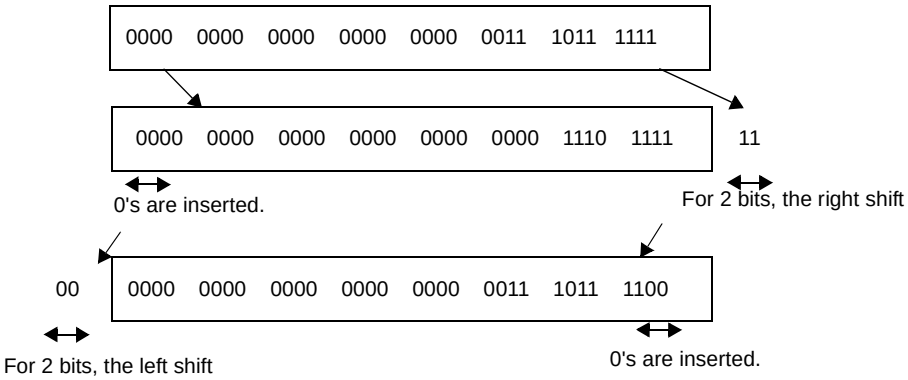
```
mov32   0x21 << 2, r20          ; (1)
```

(1) This operator shifts the value "0x21" to the left by 2 bits.
"0x84" is forwarded to r20.
Therefore, (1) in the above example can also be described as: mov32 0x84, r20.




```
mov32   0x3BF >> 2 << 2, r20    ; (2)
```

(2) This operator shifts the value "0x3B" to the right by 2 bits, and shifts to the left by 2 bits.
"0x3BC" is forwarded to r20.
Therefore, (2) in the above example can also be described as: mov32 0x3BC, r20.



4.1.7 Byte separation operators

The following byte separation operators are available.

Operator	Overview
HIGH	Returns the high-order 8-bit value of a term.
LOW	Returns the low-order 8-bit value of a term.

HIGH

Returns the high-order 8-bit value of a term.

[Function]

Returns the high-order 8-bit value of a term.

[Application example]

```
mov     HIGH(0x1234), r10       ; (1)
```

(1) By executing a mov instruction, this operator returns the high-order 8-bit value "0x12" of the expression "0x1234".
Therefore, (1) in the above example can also be described as: mov 0x12, r10.

LOW

Returns the low-order 8-bit value of a term.

[Function]

Returns the low-order 8-bit value of a term.

[Application example]

```
mov     LOW(0x1234), r10        ; (1)
```

(1) By executing a mov instruction, this operator returns the low-order 8-bit value "0x34" of the expression "0x1234".
Therefore, (1) in the above example can also be described as: mov 0x34, r10.

4.1.8 2-byte separation operators

The following 2-byte separation operators are available.

Operator	Overview
HIGHW	Returns the high-order 16-bit value of a term.
LOWW	Returns the low-order 16-bit value of a term.
HIGHW1	The value calculated by adding the value at the 15th bit to the uppermost 16 bits of the term.

HIGHW

Returns the high-order 16-bit value of a term.

[Function]

Returns the high-order 16-bit value of a term.

[Application example]

```
movea   HIGHW(0x12345678), R0, r10      ; (1)
```

(1) By executing a movea instruction, this operator returns the high-order 16-bit value "0x1234" of the expression "0x12345678".
Therefore, (1) in the above example can also be described as: movea 0x1234, R0, r10.

LOWW

Returns the low-order 16-bit value of a term.

[Function]

Returns the low-order 16-bit value of a term.

[Application example]

```
movea   LOWW(0x12345678), R0, r10       ; (1)
```

(1) By executing a movea instruction, this operator returns the low-order 16-bit value "0x5678" of the expression "0x12345678".
Therefore, (1) in the above example can also be described as: movea 0x5678, R0, r10.

HIGHW1

The value calculated by adding the value at the 15th bit to the uppermost 16 bits of the term.

[Function]

The value calculated by adding the value at the 15th bit to the uppermost 16 bits of the term.

[Application example]

```
movhi   HIGHW1(0x12348765), R0, r10     ; (1)
```

(1) Given the value 0x12348765, a movhi instruction adds the value at the 15th bit (1) to the top 16 bits (0x1234), returning the value 0x1235.
Therefore, (1) in the above example can also be described as: movhi 0x1235, R0, r10.

4.1.9 Section aggregation operators

The following section aggregation operators are available.

Operator	Overview
STARTOF	Returns the start address of the term section after linking.
SIZEOF	Returns the size of the term section after linking.

STARTOF

Returns the start address of the term section after linking.

[Function]

Returns the start address of the term section after linking.

[Application example]

```
.DW     STARTOF(.text)          ; (1)
```

(1) Allocates a 4-byte area, and initializes it with the start address of the .text section.

Each section and its alignment condition must be specified.

```
.DW         STARTOF(user.text)
.SECTION    user.text, TEXT
.ALIGN      4
```

The alignment condition can be omitted if the default condition for that section is to be used.

```
.DW         STARTOF(user.text)
.SECTION    user.text, TEXT
```

The section definition and alignment condition can be omitted if the default section name and default alignment condition are to be used for that section.

```
.DW         STARTOF(.text)
```

To use this operator in conjunction with SIZEOF:

```
.DW         STARTOF(.data) + SIZEOF(.data)
```

To specify a section name that begins with a number:

```
.DW         STARTOF(123.user.text)
.SECTION    "123.user.text", TEXT
```

[Caution]

- STARTOF can only be written as an operand of the data definition directive, .dw.
- Section names that are not defined in the same module are not specifiable.
  For this reason, if a section is defined in another module, the section definition directive you use to define the section and the .align directive you use to adjust its alignment condition must match those of the definitions of the same section in other modules.
  If a section is specified but has not been defined or has a different alignment condition to that selected in another module, the following messages are output.

- When the section has not been defined:

E0550249: Illegal syntax.

- When the section has a different alignment condition:

W0561322: Section alignment mismatch : "*section*"

- You can omit the section definitions and .align directives when default section names and default values of the alignment conditions are to be used, respectively.
- This operator can be specified in combination with SIZEOF by using the binary operator "+".
  Note, however, that it is not possible on the same line to write multiple instances of STARTOF and SIZEOF or include an expression other than STARTOF or SIZEOF.

SIZEOF

Returns the size of the term section after linking.

[Function]

Returns the size of the term section after linking.

[Application example]

```
.DW     SIZEOF(.text)           ; (1)
```

(1) Allocates a 4-byte area, and initializes it with the size of the .text section.

Each section and its alignment condition must be specified.

```
.DW         SIZEOF(user.text)
.SECTION    user.text, TEXT
.ALIGN      4
```

The alignment condition can be omitted if the default condition for that section is to be used.

```
.DW         SIZEOF(user.text)
.SECTION    user.text, TEXT
```

The section definition and alignment condition can be omitted if the default section name and default alignment condition are to be used for that section.

```
.DW         SIZEOF(.text)
```

To use this operator in conjunction with STARTOF:

```
.DW         STARTOF(.data) + SIZEOF(.data)
```

To specify a section name that begins with a number:

```
.DW         SIZEOF(123.user.text)
.SECTION    "123.user.text", TEXT
```

[Caution]

- SIZEOF can only be written as an operand of the data definition directive, .dw.
- Section names that are not defined in the same module are not specifiable.
  For this reason, if a section is defined in another module, the section definition directive you use to define the section and the .align directive you use to adjust its alignment condition must match those of the definitions of the same section in other modules.
  If a section is specified but has not been defined or has a different alignment condition to that selected in another module, the following messages are output.

- When the section has not been defined:

E0550249: Illegal syntax.

- When the section has a different alignment condition:

W0561322: Section alignment mismatch : "*section*"

- You can omit the section definitions and .align directives when default section names and default values of the alignment conditions are to be used, respectively.
- This operator can be specified in combination with STARTOF by using the binary operator "+".
  Note, however, that it is not possible on the same line to write multiple instances of STARTOF and SIZEOF or include an expression other than STARTOF or SIZEOF.

4.1.10 Other operator

The following operators is also available.

Operator	Overview
( )	Prioritizes the calculation within ( ).

( )

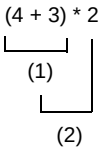
Prioritizes the calculation within ( ).

[Function]

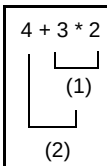
Causes an operation in parentheses to be performed prior to operations outside the parentheses.
This operator is used to change the order of precedence of other operators.
If parentheses are nested at multiple levels, the expression in the innermost parentheses will be calculated first.

[Application example]

```
mov     (4 + 3) * 2, r10
```



Calculations are performed in the order of expressions (1), (2) and the value "14" is returned as a result.
If parentheses are not used,



Calculations are performed in the order (1), (2) shown above, and the value "10" is returned as a result.
See "Table 4-4. Operator Precedence Levels", for the order of precedence of operators.

4.1.11 Restrictions on operations

An expression consists of a "constant", "symbol", "label reference", "operator", and "parentheses".It indicates a value consisting of these elements. The expression distinguishes between Absolute expression and Relative expressions.

(1) Absolute expression

An expression indicating a constant is called an "absolute expression". An absolute expression can be used when an operand is specified for an instruction or when a value etc. is specified for a directive. An absolute expression usually consists of a constant or symbol. The following format is treated as an absolute expression.

(a) Constant expression

If a reference to a previously defined symbol is specified, assumes that the constant of the value defined for the symbol has been specified. Therefore, a defined symbol reference can be used in a constant expression.

Example

```
SYM1    .set    0x100       --Define symbol SYM1
        mov     SYM1, r10   --SYM1, already defined, is treated as a constant
                              expression.
```

(b) Symbol

The expressions related to symbols are the following ("±" is either "+" or "-").

- Symbol
- Symbol ± constant expression
- Symbol - symbol
- Symbol - symbol ± constant expression

A "symbol" here means an undefined symbol reference at that point. If a reference to a previously defined symbol is specified, assumes that the "constant" of the value defined for the symbol has been specified.

Example

```
        add     SYM1 + 0x100, r11   --SYM1 is an undefined symbol at this point
SYM1    .set    0x10                --Defines SYM1
```

(c) Label reference

The following expressions are related to label reference ("±" is either "+" or "-").

- Label reference - label reference
- Label reference - label reference ± constant expression

Here is an example of an expression related to a label reference.

Example

```
mov     $label1 - $label2, r11
```

A "reference to two labels" as shown in this example must be referenced as follows.

- The same section has a definition in the specified file.
- Same reference method (such as $label and $label, and #label and #label)

When not meeting these conditions, a message is output, and assembly is canceled.

However, if a reference to the absolute address of a label not having a definition in the specified file is specified as label reference on one side of "- label reference" in an "expression related to label reference", it is assumed that the same reference method as that of the label on the other side is used, because of the current organization of the assembler. Note that an absolute expression in this format cannot be specified for a branch instruction. If such an expression is specified, a message is output, and assembly is canceled. The .DW directive can be assembled if two label accesses are absolute address references, even if the definitions are in different sections of different files.

(2) Relative expressions

An expression indicating an offset from a specific address[Note 1] is called a "relative expression". A relative expression is used to specify an operand by an instruction or to specify a value by data definition directive. A relative expression usually consists of a label reference. The following format[Note 2] is treated as an relative expression.

Notes 1. This address is determined when the optimizing linker is executed. Therefore, the value of this offset may also be determined when the optimizing linker is executed.

2. The absolute value system and the relative value system can regard an expression in the format of "-symbol + label reference", as being an expression in the format of "label reference - symbol," but it cannot regard an expression in the format of "label reference - (+symbol)" as being an expression in the format of "label reference - symbol". Therefore, use parentheses "( )" only in constant expressions.

(a) Label reference

The following expressions are related to label reference ("±" is either "+" or "-").

- Label reference
- Label reference + constant expression
- Label reference - symbol
- Label reference - symbol ± constant expression

Here is an example of an expression related to a label reference.

Example

```
SIZE    .set    0x10
        add     #label1, r10
        add     #label1 + 0x10, r10
        add     #label2 ? SIZE, r10
        add     #label2 ? SIZE + 0x10, r10
```

4.1.12 Identifiers

An identifier is a name used for symbols, labels, macros etc.

Identifiers are described according to the following basic rules.

- Identifiers consist of alphanumeric characters and symbols that are used as characters (@,_, .)
  However, the first character cannot be a number (0 to 9).
- Reserved words cannot be used as identifiers.
  With regard to reserved words, see "4.5 Reserved Words".
- The assembler distinguishes between uppercase and lowercase.

4.2 Directives

This section explains the directives.

Directives are instructions that direct all types of instructions necessary for the assembler.

4.2.1 Outline

Instructions are translated into machine language as a result of assembling, but directives are not converted into machine language in principle.

Directives contain the following functions mainly:

- To facilitate description of source programs
- To initialize memory and reserve memory areas
- To provide the information required for assemblers and optimizing linkers to perform their intended processing

The following table shows the types of directives.

Table 4-5. List of Directives

Type	Directives
Section definition directives	.cseg, .dseg, .section, .org
Symbol definition directives	.set
Compiler output directives	.file, .line, .stack, ._line_top, ._line_end
Data definition/Area reservation directives	.db, .db2/.dhw, .dshw, .db4/.dw, .db8/.ddw, .float, .double, .ds, .align
External definition/External reference directives	.public, .extern
Macro directives	.macro, .local, .rept, .irp, .exitm, .exitma, .endm

The following sections explain the details of each directive.

In the description format of each directive, "[ ]" indicates that the parameter in square brackets may be omitted from specification, and "..." indicates the repetition of description in the same format.

4.2.2 Section definition directives

A section is a block of routines or data of the same type. A "section definition directive" is a directive that declares the start or end of a section.

Sections are the unit of allocation in the optimizing linker.

Example

```
.cseg
  :
.dseg
  :
```

Two sections with the same section name must have the same relocation attribute. Consequently, multiple sections with differing relocation attributes cannot be given the same section name. If two sections with the same section name have different relocation attributes, an error will occur.

Sections can be broken up. In other words, sections in a single source program file with the same relocation attribute and section name will be processed as a single continuous section in the assembler.

If the sections are broken into separate source program files, then they will be processed by the optimizing linker.

Section names cannot be referenced as symbols.

The following section definition directives are available.

Table 4-6. Section Definition Directives

Directive	Overview
.cseg	Indicates to the assembler the starting of a code section
.dseg	Indicates to the assembler the start of a data section
.section	Indicates to the assembler the start of a section
.org	Indicates to the assembler the start of a section at an absolute address
.offset	Specifies an offset from the first address of a section

.cseg

Indicate to the assembler the start of a code section.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*section-name*]	.cseg	[*relocation-attribute*]	[; *comment*]

[Function]

- The .cseg directive indicates to the assembler the start of a code section.
- All instructions described following the .cseg directive belong to the code section until it comes across a section definition directives.

[Use]

- The .cseg directive is used to describe instructions, .db, .dw directives, etc. in the code section defined by the .cseg directive.
- Description of one functional unit such as a subroutine should be defined as a single code section.

[Description]

- The start address of a code section can be specified with the .org directive.
- A relocation attribute defines a range of location addresses for a code section.

Table 4-7. Relocation Attributes of .cseg

Relocation Attribute	Description Format	Explanation	Default Value of Alignment Condition
TEXT	TEXT	Allocates the program.	2
ZCONST	ZCONST	This section is for constant (read-only) data. It allocates a memory range (up to 32 Kbytes, in the positive direction from r0), referenced with 1 instructions using r0 and 16-bit displacement.	4
ZCONST23	ZCONST23	This section is for constant (read-only) data. It allocates a memory range (up to 4 Mbytes, in the positive direction from r0), referenced with 1 instructions using r0 and 23-bit displacement.	4
CONST	CONST	This section is for constant (read-only) data. It allocates a memory range (up to 4 Gbytes, in the positive direction from r0), referenced with 2 instructions using r0 and 32-bit displacement.	4

- If there is a label or an instruction to output object code before a section definition directive, a relocatable code section is generated as the default section. The section name here will be ".text", and the relocation attribute will be "TEXT".
- The assembler will output an error if a relocation attribute other than "Table 4-7. Relocation Attributes of .cseg" is specified.
- By describing a section name in the symbol field of the .cseg directive, the code section can be named. If no section name is specified for a code section, the assembler will automatically give a default section name to the code section.
  The default section names of the code sections are shown below.

Relocation Attribute	Default Section Name
TEXT	.text
ZCONST	.zconst
ZCONST23	.zconst23
CONST	.const

The default section names have the relocation attributes shown above. Giving them any other attributes is not possible.

- If you wish to specify a number as first character with a section name, enclose each file name with a double quotation (").

Example

```
test        .cseg   text
            nop
            nop
"test"      .cseg   text
            nop
            nop
"123test"   .cseg   text
            nop
            nop
```

- The following characters are usable in section names.
  - Alphanumeric characters (0-9, a-z, A-Z)
  - Special characters (@, _, .)

.dseg

Indicate to the assembler the start of a data section.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*section-name*]	.dseg	[*relocation-attribute*]	[; *comment*]

[Function]

- The .dseg directive indicates to the assembler the start of a data section.
- A memory following the .dseg directive belongs to the data section until it comes across a section definition directives.

[Use]

- The .ds directive is mainly described in the data section defined by the .dseg directive.

[Description]

- The start address of a data section can be specified with the .org directive.
- A relocation attribute defines a range of location addresses for a data section.
  The relocation attributes available for data sections are shown below.

Table 4-8. Relocation Attributes of .dseg

Relocation Attribute	Description Format	Explanation	Default Value of Alignment Condition
SDATA	SDATA	Allocates a memory range (up to 64 Kbytes, combined with SBSS section), referenced with 1 instructions using gp and 16-bit displacement, having an initial value.	4
SBSS	SBSS	Allocates a memory range (up to 64 Kbytes, combined with SDATA section), referenced with 1 instructions using gp and 16-bit displacement, not having an initial value.	4
SDATA23	SDATA23	Allocates a memory range (up to 8MKbytes, combined with SBSS23 section), referenced with 1 instructions using gp and 23-bit displacement, having an initial value.	4
SBSS23	SBSS23	Allocates a memory range (up to 8Mbytes, combined with SDATA23 section), referenced with 1 instructions using gp and 23-bit displacement, not having an initial value.	4
TDATA	TDATA	Allocates a memory range (up to 256 bytes, in the positive direction from ep), referenced with 1 instructions using ep, having an initial value.	4
TDATA4	TDATA4	Allocates a memory range(up to 16 bytes, in the positive direction from ep), referenced with 1 instructions using ep and 4-bit displacement, having an initial value.	4

Relocation Attribute	Description Format	Explanation	Default Value of Alignment Condition
TBSS4	TBSS4	Allocates a memory range (up to 16 bytes, in the positive direction from ep), referenced with 1 instructions using ep and 4-bit displacement, not having an initial value.	4
TDATA5	TDATA5	Allocates a memory range(up to 32 bytes, in the positive direction from ep), referenced with 1 instructions using ep and 5-bit displacement, having an initial value.	4
TBSS5	TBSS5	Allocates a memory range (up to 32 bytes, in the positive direction from ep), referenced with 1 instructions using ep and 5-bit displacement, not having an initial value.	4
TDATA7	TDATA7	Allocates a memory range(up to 128 bytes, in the positive direction from ep), referenced with 1 instructions using ep and 7-bit displacement, having an initial value.	4
TBSS7	TBSS7	Allocates a memory range (up to 128 bytes, in the positive direction from ep), referenced with 1 instructions using ep and 7-bit displacement, not having an initial value.	4
TDATA8	TDATA8	Allocates a memory range(up to 256 bytes, in the positive direction from ep), referenced with 1 instructions using ep and 8-bit displacement, having an initial value.	4
TBSS8	TBSS8	Allocates a memory range (up to 256 bytes, in the positive direction from ep), referenced with 1 instructions using ep and 8-bit displacement, not having an initial value.	4
EDATA	EDATA	Allocates a memory range (up to 64 Kbytes, combined with EBSS section), referenced with 1 instructions using ep and 16-bit displacement, having an initial value.	4
EBSS	EBSS	Allocates a memory range (up to 64 Kbytes, combined with EDATA section), referenced with 1 instructions using ep and 16-bit displacement, not having an initial value.	4
EDATA23	EDATA23	Allocates a memory range (up to 8 Mbytes, combined with EBSS23 section), referenced with 1 instructions using ep and 16-bit displacement, having an initial value.	4
EBSS23	EBSS23	Allocates a memory range (up to 8 Mbytes, combined with EDATA23 section), referenced with 1 instructions using ep and 16-bit displacement, not having an initial value.	4
ZDATA	ZDATA	Allocates a memory range (up to 32 Kbytes, combined with ZBSS section, in the negative direction from r0), referenced with 1 instructions using r0 and 16-bit displacement, having an initial value.	4
ZBSS	ZBSS	Allocates a memory range (up to 32 Kbytes, combined with ZDATA section, in the negative direction from r0), referenced with 1 instructions using r0 and 16-bit displacement, not having an initial value.	4
ZDATA23	ZDATA23	Allocates a memory range (up to 4 Mbytes, combined with ZBSS23 section, in the negative direction from r0), referenced with 1 instructions using r0 and 23-bit displacement, having an initial value.	4

Relocation Attribute	Description Format	Explanation	Default Value of Alignment Condition
ZBSS23	ZBSS23	Allocates a memory range (up to 4 Mbytes, combined with ZDATA23 section, in the negative direction from r0), referenced with 1 instructions using r0 and 23-bit displacement, not having an initial value.	4
DATA	DATA	Allocates a memory range (up to 4 Gbytes, combined with BSS section, in the negative direction from r0), referenced with 1 instructions using r0 and 32-bit displacement, having an initial value.	4
BSS	BSS	Allocates a memory range (up to 4 Gbytes, combined with DATA section, in the negative direction from r0), referenced with 1 instructions using r0 and 32-bit displacement, not having an initial value.	4

Note If a section with the TDATA relocation attribute is defined in multiple files of source code, linkage of the code will lead to an error.

- The assembler will output an error if a relocation attribute other than "Table 4-8. Relocation Attributes of .dseg" is specified.
- Machine language instructions cannot be described in a data section with BSS relocation attributes. If described, an error is output.
- By describing a section name in the symbol field of the .dseg directive, the data section can be named. If no section name is specified for a data section, the assembler automatically gives a default section name.
  The default section names of the data sections are shown below.

Relocation Atribute	Default Section Name
SDATA	.sdata
SBSS	.sbss
SDATA23	.sdata23
SBSS23	.sbss23
TDATA[Note]	.tdata
TDATA4	.tdata4
TBSS4	.tbss4
TDATA5	.tdata5
TBSS5	.tbss5
TDATA7	.tdata7
TBSS7	.tbss7
TDATA8	.tdata8
TBSS8	.tbss8
EDATA	.edata
EBSS	.ebss
EDATA23	.edata23
EBSS23	.ebss23

Relocation Atribute	Default Section Name
ZDATA	.zdata
ZBSS	.zbss
ZDATA23	.zdata23
ZBSS23	.zbss23
DATA	.data
BSS	.bss

Note A specification possible section name is only a default section name in TDATA relocation attributes. But, it is possible to omit.

The default section names have the relocation attributes shown above. Giving them any other attributes is not possible.

- If you wish to specify a number as first character with a section name, enclose each file name with a double quotation (").

Example

```
test        .dseg   data
            .dw     0x1234
            .dw     0x5678
"test"      .dseg   data
            .dw     0x1234
            .dw     0x5678
"123test"   .dseg   data
            .dw     0x1234
            .dw     0x5678
```

- The following characters are usable in section names.
  - Alphanumeric characters (0-9, a-z, A-Z)
  - Special characters (@, _, .)

.section

Indicate to the assembler the start of section.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	.section	*section-name, relocation-attribute*	[; *comment*]

[Function]

- The .section directive indicates to the assembler the start of a section (no separation of code and data).

[Use]

- You can define all sections that can be defined via .cseg or .dseg directives using the .section directive, rather than differentiating code and data sections using the .cseg and .dseg directives.

.org

Indicate the start of a section at an absolute address to the assembler.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	.org	*absolute-expression*	[; *comment*]

[Function]

- Indicate the start of a section at an absolute address to the assembler.
- After the .org directive, it is valid until the next section definition directive.
- The range from the .org directive to the line with the next section definition directive (.cseg, .dseg, .section or .org) is regarded as a section where the code is placed at absolute addresses.
- The name of each section starting at an absolute address takes the form of "section for which .org was written" + ".AT" + "specified address". The relocation attribute is the same as that of the section for which .org was written.
- If .org is written prior to a section definition directive at the beginning of a file of source code, the name of the section will be ".text.AT" + "specified address" and the relocation attribute will be "TEXT".

[Example]

If .org is written immediately after a section definition directive, the section is only generated from the absolute address.

```
.section    "My_text", text
.org        0x12                    ;"My_text.AT12" is allocated to address 0x12
mov         r10, r11
.org        0x30                    ;"My_text.AT30" is allocated to address 0x30
mov         r11, r12
```

If the .org directive does not immediately follow the section definition directive, only the range of code from the .org directive is a section starting at the given absolute address.

```
.section    "My_text", text
nop                                 ;Allocated in "My_text"
.org        0x50
mov         r10, r11                ;Allocated in "My_text.AT50"
```

[Caution]

- The operand value is in accordance with "Absolute expression". An illegal value will lead to an error and cause processing to end.
- The overall definition of a single section may contain multiple .org directives. Note, however, that an error will occur if an address specified for a section by .org is in an address range to which another section starting at an absolute address has been allocated in the same file.
- A .org directive is not allowed for a section that has the TDATA relocation attribute. Doing so will lead to an error and cause processing to end.

.offset

Specifies an offset from the first address of a section.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	.offset	*absolute-expression*	[; *comment*]

[Function]

- The .offset directive specifies an offset from the first address of a section that holds instruction code for the lines following the .offset directive.
- After the .org directive, it is valid until the next section definition directive.
- If .offset is written prior to any section definition directive at the beginning of a source program, the name of the section will be ".text" and the relocation attribute will be "TEXT".
- Section names can also be enclosed in double-quotation marks (").
  If you wish to specify a number as first character with a section name, enclose each file name with a double quotation (").

Example

```
.section    "My_data", data
.offset     0x12
mov         r10, r11            ; The offset is 0x12
```

[Caution]

- The operand value is in accordance with "Absolute expression". An illegal value will lead to an error and cause processing to end.
- The overall definition of a single section may contain multiple .org directives. Note, however, that an error occurs when the specified value is smaller than that for a preceding .offset directive.
- The value specified as an operand of the .offset directive must be an Absolute expression in the range of 0x0 to 0x7fffffff.
  The actual value is limited by the memory size of the host machine where the program runs.

4.2.3 Symbol definition directives

Symbol definition directives specify symbols for the data that is used when writing to source modules. With these, the data value specifications are made clear and the details of the source module are easier to understand.

Symbol definition directives indicate the symbols of values used in the source module to the assembler.

The following symbol definition directives are available.

Table 4-9. Symbol Definition Directives

Directive	Overview
.set	Defines a name
.equ	Defines a symbol

.set

Defines a name.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
name	.set	*absolute-expression*	[; *comment*]

[Function]

Defines a symbol having a symbol name specified by the symbol field and a absolute-expression value specified by the operand field.

[Use]

- You can use this directive to define names for numerical data that can be used instead of the actual numbers in the operands of machine-language instructions and directives in source code.
- We recommend defining frequently used numerical values as names. Even if a given value in the source program is to be changed, you will only need to change the value corresponding to the name.

[Description]

- Incorrect formats for an operand will cause processing to end.
- The .set directive may be described anywhere in a source program.
- Each name is a redefinable symbol.
- Names cannot be externally defined.

[Example]

Defines the value of symbol sym1 as 0x10.

```
sym1    .set 0x10
```

[Caution]

- Any label reference or undefined symbol reference must not be used to specify a value.
  Otherwise, the assembler outputs the following message then stops assembling.

```
E0550203: illegal expression (string)
```

- If a label name, a macro name defined by the .macro directive, or a symbol of the same name as a formal parameter of a macro is specified, the assembler outputs the following message and stops assembling.

```
E0550212: symbol already define as string
```

.equ

Defines a symbol.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
symbol	.equ	*absolute-expression*	[; *comment*]

[Function]

Defines a symbol having a symbol name specified by the symbol field and a absolute-expression value specified by the operand field.

[Use]

- You can use this directive to define symbols for numerical data that can be used instead of the actual numbers in the operands of machine-language instructions and directives in source code.

[Description]

- Incorrect formats for an operand will cause processing to end.
- The .set directive may be described anywhere in a source program.
- Symbols that have already been defined by using .equ cannot be redefined.
- The symbol generated by the .equ directive can be externally defined by the .public directive.

4.2.4 Compiler output directives

Compiler output directives inform the assembler of information output by the compiler, such as compiler debugging information.

The following compiler output directives are available.

Table 4-10. Compiler Output Directives

Directive	Overview
.file	Generates a symbol table entry
.line	Line-number information from the C source program
.stack	Defines the stack amount of consumption for a symbol
._line_top	Information specified by the compiler #pragma inline_asm statement
._line_end	Information specified by the compiler #pragma inline_asm statement

.file

Generates a symbol table entry (FILE type).

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	.file	"*file-name*"	[; *comment*]

[Function]

- The ".file" directive is compiler debugging information.

[Description]

- The file name is written with the specified image.
- This is the name of the C source program file that the compiler outputs.

.line

Line-number information from the C source program.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	.line	["*file-name*",] *line-number*	[; *comment*]

[Function]

- The ".func" directive is compiler debugging information.

[Description]

- Modifies the line numbers and filenames referenced during debugging.
- The line numbers and filenames in the source program are not updated between the first .line directive and the next one.
- If the filename is omitted, then only the line number is changed.
- This is the line-number information of the C source program that the compiler outputs.

.stack

Defines the stack amount of consumption for a symbol.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	.stack	*symble-name=value*	[; *comment*]

[Function]

- The ".stack" directive is compiler debugging information.

[Description]

- This defines the stack amount of consumption for a symbol.
- The stack amount of consumption for a symbol can only be defined once, and subsequent definitions are ignored.
- The stack amount of consumption can only be defined as a 4-byte range of 0x0 to 0xFFFFFFFC. If a different value is specified, then the definition is ignored.
- This is the function information of the C source program that the compiler outputs.

._line_top

Information specified by the compiler #pragma inline_asm statement.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	._line_top	inline_asm	[; *comment*]

[Function]

- The ._line_top directive is the information specified by the compiler #pragma inline_asm statement.

[Description]

- This is the #pragma inline_asm statement information of the C source program that the compiler outputs.
- The ._line_top directive indicates the start of the instructions for a function which has been specified as inline_asm.

[Caution]

- Assembler control instructions are not usable in assembly code for functions specified as inline_asm. In addition, only the directives listed below are usable. Specifying any other directive will lead to an error.
  - data definition directives (.db/.db2/.dhw/.db4/.dw/.db8/.ddw/.dshw/.ds/.float/.double)
  - macro directives (.macro/.irp/.rept/.local)
- Defining labels other than local labels is forbidden in functions specified as inline_asm. Defining any other labels will lead to errors.

._line_end

Information specified by the compiler #pragma inline_asm statement.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	._line_end	inline_asm	[; *comment*]

[Function]

- The ._line_end directive is the information specified by the compiler #pragma inline_asm statement.

[Description]

- This is the #pragma inline_asm statement information of the C source program that the compiler outputs.
- The ._line_end directive indicates the end of the instructions for a function which has been specified as inline_asm.

[Caution]

- Assembler control instructions are not usable in assembly code for functions specified as inline_asm. In addition, only the directives listed below are usable. Specifying any other directive will lead to an error.
  - data definition directives (.db/.db2/.dhw/.db4/.dw/.db8/.ddw/.dshw/.ds/.float/.double)
  - macro directives (.macro/.irp/.rept/.local)
- Defining labels other than local labels is forbidden in functions specified as inline_asm. Defining any other labels will lead to errors.

4.2.5 Data definition/Area reservation directives

The data definition directive defines the constant data used by the program.

The defined data value is generated as object code.

The area reservation directive secures the area for memory used by the program.

The following data definition and partitioning directives are available.

Table 4-11. Data Definition/Area Reservation Directives

Directive	Overview
.db	Initialization of byte area
.db2/.dhw	Initialization of 2-byte area
.dshw	Initializes a 2-byte area with the specified value, right-shifted one bit
.db4/.dw	Initialization of 4-byte area
.db8/.ddw	Initialization of 8-byte area
.float	Initialization of 4-byte area
.double	Initialization of 8-byte area
.ds	Secures the memory area of the number of bytes specified by operand
.align	Aligns the value of the location counter

.db

Initialization of byte area.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.db	(*absolute-expression*)	[; *comment*]
		or	
[*label*:]	.db	*expression*[, ...]	[; *comment*]
		or	
[*label*:]	.db	*"Character string constants"*	[; *comment*]

[Function]

- The .db directive tells the assembler to initialize a byte area.
  The number of bytes to be initialized can be specified as "size".
- The .db directive also tells the assembler to initialize a memory area in byte units with the initial value(s) specified in the operand field.

[Use]

- Use the .db directive when defining an expression or character string used in the program.

[Description]

- If a value in the operand field is parenthesized, the assembler assumes that a size is specified. Otherwise, an initial value is assumed.

(1) With size specification:

(a) If a size is specified in the operand field, the assembler initializes an area equivalent to the specified number of bytes with the value "0".

(b) An absolute expression can be described as a size. If the size description is illegal, the CC-RH outputs an error message and will not execute initialization.

(2) With initial value specification:

(a) Expression

The value of an expression must be 1-byte data. Therefore, the value of the operand must be in the range of 0x0 to 0xFF. If the value exceeds 1 byte, the assembler will use only lower 1 byte of the value as valid data.

(b) Character string constants

If the first operand is surrounded by corresponding double quotes ("), then it is assumed to be a string constant.

If a character string constants is described as the operand, an 8-bit ASCII code will be reserved for each character in the string.

- Two or more initial values may be specified within a statement line of the .db directive.
- As an initial value, an expression that includes a relocatable symbol or external reference symbol may be described.
- If the relocation attribute of the section containing the .db directive is "BSS", then an error is output because initial values cannot be specified.

[Example]

```
                .cseg   text
WORK1:          .db     (1)                     ; (1)
WORK2:          .db     (2)                     ; (1)
                .cseg   text
MASSAG:         .db     "ABCDEF"                ; (2)
DATA1:          .db     0xA, 0xB, 0xC           ; (3)
DATA2:          .db     (3 + 1)                 ; (4)
DATA3:          .db     "AB" + 1                ; (5)   <- Error
```

(1) Because the size is specified, the assembler will initialize each byte area with the value "0".

(2) A 6-byte area is initialized with character string 'ABCDEF'

(3) A 3-byte area is initialized with "0xA, 0xB, 0xC".

(4) A 4-byte area is initialized with "0x0".

(5) This description occurs in an error.

.db2/.dhw

Initialization of 2-byte area.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.db2	(*absolute-expression*)	[; *comment*]
		or	
[*label*:]	.db2	*expression*[, ...]	[; *comment*]
		or	
[*label*:]	.dhw	(*absolute-expression*)	[; *comment*]
		or	
[*label*:]	.dhw	*expression*[, ...]	[; *comment*]

[Function]

- The .db2 and .dhw directive tells the assembler to initialize 2-byte area.
  The number of 2-byte data to be initialized can be specified as "size".
- The .db2 and .dhw directive also tells the assembler to initialize a memory area in 2-byte units with the initial value(s) specified in the operand field.

[Use]

- Use the .db2 and .dhw directive when defining a 2-byte numeric constant such as an address or data used in the program.

[Description]

- If a value in the operand field is parenthesized, the assembler assumes that a size is specified. Otherwise, an initial value is assumed.

(1) With size specification:

(a) If a size is specified in the operand field, the assembler initializes an area equivalent to the specified number of 2-byte with the value "0".

(b) An absolute expression can be described as a size. If the size description is illegal, the CC-RH outputs an error message and will not execute initialization.

(2) With initial value specification:

(a) Expression

The value of an expression must be 2-byte data. Therefore, the value of the operand must be in the range of 0x0 to 0xFFFF. If the value exceeds 2-byte, the assembler will use only lower 2-byte of the value as valid data.

No character string constants can be described as an initial value.

- If the relocation attribute of the section containing the .db2 and .dhw directive is "BSS", then an error is output because initial values cannot be specified.
- Two or more initial values may be specified within a statement line of the .db2 and .dhw directive.
- As an initial value, an expression that includes a relocatable symbol or external reference symbol may be described.

.dshw

Initializes a 2-byte area with the specified value, right-shifted one bit.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.dshw	*expression*[, ...]	[; *comment*]

[Function]

- Initializes a 2-byte area with the specified value, right-shifted one bit.

[Description]

- The value is secured as 2-byte data, as the value of the expression right-shifted 1 bit.
- If the relocation attribute of the section is "BSS", then an error is output because the .dshw directive cannot be described.
- It is possible to code an absolute expression in the operand expression.
- The value of the expression, right-shifted one bit, must be in the range 0x0 to 0xFFF. In other cases, the data from the lower two bytes will be secured.
- Any number of expressions may be specified on a single line, by separating them with commas.
- It is not possible to code string constants in the operand.

.db4/.dw

Initialization of 4-byte area.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.db4	(*absolute-expression*)	[; *comment*]
		or	
[*label*:]	.db4	*expression*[, ...]	[; *comment*]
		or	
[*label*:]	.dw	(*absolute-expression*)	[; *comment*]
		or	
[*label*:]	.dw	*expression*[, ...]	[; *comment*]

[Function]

- The .db4 and .dw directive tells the assembler to initialize 4-byte area.
  The number of 4-byte data to be initialized can be specified as "size".
- The .db4 and .dw directive also tells the assembler to initialize a memory area in 4-byte units with the initial value(s) specified in the operand field.

[Use]

- Use the .db4 and .dw directive when defining a 4-byte numeric constant such as an address or data used in the program.

[Description]

- If a value in the operand field is parenthesized, the assembler assumes that a size is specified. Otherwise, an initial value is assumed.

(1) With size specification:

(a) If a size is specified in the operand field, the assembler initializes an area equivalent to the specified number of 4-byte with the value "0".

(b) An absolute expression can be described as a size. If the size description is illegal, the CC-RH outputs an error message and will not execute initialization.

(2) With initial value specification:

(a) Expression

The value of an expression must be 4-byte data. Therefore, the value of the operand must be in the range of 0x0 to 0xFFFFFFFF. If the value exceeds 4-byte, the assembler will use only lower 2-byte of the value as valid data.
No character string constants can be described as an initial value.

- Two or more initial values may be specified within a statement line of the .db4 and .dw directive.

- As an initial value, an expression that includes a relocatable symbol or external reference symbol may be described.
- If the relocation attribute of the section containing the .db4 and .dw directive is "BSS", then an error is output because initial values cannot be specified.

.db8/.ddw

Initialization of 8-byte area.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.db8	(*absolute-expression*)	[; *comment*]
		or	
[*label*:]	.db8	*absolute-expression*[, ...]	[; *comment*]
		or	
[*label*:]	.ddw	(*absolute-expression*)	[; *comment*]
		or	
[*label*:]	.ddw	*absolute-expression*[, ...]	[; *comment*]

[Function]

- The .db8 and .ddw directive tells the assembler to initialize 8-byte area.
  The number of 8-byte data to be initialized can be specified as "size".
- The .db8 and .ddw directive also tells the assembler to initialize a memory area in 8-byte units with the initial value(s) specified in the operand field.

[Use]

- Use the .db8 and .ddw directive when defining a 8-byte numeric constant such as an address or data used in the program.

[Description]

- If a value in the operand field is parenthesized, the assembler assumes that a size is specified. Otherwise, an initial value is assumed.

(1) With size specification:

(a) If a size is specified in the operand field, the assembler initializes an area equivalent to the specified number of 8-byte with the value "0".

(b) An absolute expression can be described as a size. If the size description is illegal, the CC-RH outputs an error message and will not execute initialization.

(2) With initial value specification:

(a) Expression

The value of an expression must be 8-byte data. Therefore, the value of the operand must be in the range of 0x0 to 0xFFFFFFFFFFFFFFFF. If the value exceeds 8-byte, the assembler will use only lower 8-byte of the value as valid data.
No character string constants can be described as an initial value.

- If the relocation attribute of the section is "BSS", then an error is output because the .db8 and .ddw directive cannot be described.
- Two or more initial values may be specified within a statement line of the .db8 and .ddw directive.

.float

Initialization of 4-byte area.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.float	*absolute-expression*[, ...]	[; *comment*]

[Function]

- The .float directive tells the assembler to initialize 4-byte area.
- The .float directive also tells the assembler to initialize a memory area in 4-byte units with the absolute-expression specified in the operand field.

[Description]

- The value of the absolute expression is secured as a single-precision floating-point number. Consequently, the value of the expression must be between 1.40129846e-45 and 3.40282347e+3. In other cases, the data from the lower four bytes will be secured as a single-precision floating-point number.
- If the relocation attribute of the section is "BSS", then an error is output because the .float directive cannot be described.
- Two or more absolute-expression may be specified within a statement line of the .float directive.

.double

Initialization of 8-byte area.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.double	*absolute-expression*[, ...]	[; *comment*]

[Function]

- The .double directive tells the assembler to initialize 8-byte area.
- The .double directive also tells the assembler to initialize a memory area in 8-byte units with the initial value(s) specified in the operand field.

[Description]

- The value of the absolute expression is secured as a double-precision floating-point number. Consequently, the value of the expression must be between 4.9406564584124654e-324 and 1.7976931348623157e+308. In other cases, the data from the lower eight bytes will be secured as a double-precision floating-point number.
- If the relocation attribute of the section is "BSS", then an error is output because the .double directive cannot be described.
- Two or more absolute-expression may be specified within a statement line of the .double directive.

.ds

Secures the memory area of the number of bytes specified by operand.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.ds	(*absolute-expression*)[, ...]	[; *comment*]
		or	
[*label*:]	.ds	*absolute-expression*	[; *comment*]

[Function]

- The .ds directive tells the assembler to reserve a memory area for the number of bytes specified in the operand field.

[Use]

- The .ds directive is mainly used to reserve a memory (RAM) area to be used in the program.
  If a label is specified, the value of the first address of the reserved memory area is assigned to the label. In the source module, this label is used for description to manipulate the memory.

[Description]

- If a value in the first operand is parenthesized, the assembler assumes that a size is specified. Otherwise, an initial value is assumed.
- The first operand is a size specification. If a second operand is also specified, then it will be treated as the initial value for that value.

(1) With size specification:

(a) If a size is specified in the operand, then if an initial value is specified, the compiler will fill the specified number of bytes with the specified value; otherwise, it will fill that number of bytes with zeroes ("0"). Note, however, that no area will be secured if the specified number of bytes is 0.

(b) An absolute expression can be described as a size. If the size description is illegal, the CC-RH outputs an error message and will not execute initialization.

(2) With initial value specification:

(a) Expression

The value of an expression must be byte data. Therefore, the value of the operand must be in the range of 0x0 to 0xFF. If the value exceeds byte, the assembler will use only lower 1-byte of the value as valid data.

- As an initial value, an expression that includes a relocatable symbol or external reference symbol may be described.
- If the relocation attribute of the section containing this directive is "BSS", then an error is output and this directive is ignored because initial values cannot be specified.

.align

Aligns the value of the location counter.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.align	*line-condition*[, *absolute-expression*]	[; *comment*]

[Function]

- Aligns the value of the location counter.

[Description]

- Aligns the value of the location counter for the current section, specified by the previously specified section definition directive under the alignment condition specified by the first operand. If a hole results from aligning the value of the location counter, it is filled with the value of the absolute expression specified by the second operand, or with the default value of 0.
- Specify an even number of 2 or more, but less than 2^{31}, as the alignment condition. Otherwise, the CC-RH outputs the error message then stops assembling.
- The value of the second operand's absolute-expression must be in the range of 0x0 to 0xFF. If the value exceeds range of 0x0 to 0xFF, the assembler will use only lower 1-byte of the value as valid data.
- This directive merely aligns the value of the location counter in a specified file for the section. It does not align an address after arrangement.

4.2.6 External definition/External reference directives

External definition, external reference directives clarify associations when referring to symbols defined by other modules.

This is thought to be in cases when one program is written that divides module 1 and module 2. In cases when you want to refer to a symbol defined in module 2 in module 1, there is nothing declared in either module and and so the symbol cannot be used. Due to this, there is a need to display "I want to use" or "I don't want to use" in respective modules.

An "I want to refer to a symbol defined in another module" external reference declaration is made in module 1. At the same time, a "This symbol may be referred to by other symbols" external definition declaration is made in module 2.

This symbol can only begin to be referred to after both external reference and external definition declarations in effect.

External definition, external reference directives are used to to form this relationship and the following instructions are available.

Table 4-12. External Definition/External Reference Directives

Directive	Overview
.public	Declares to the optimizing linker that the symbol described in the operand field is a symbol to be referenced from another module
.extern	Declares to the optimizing linker that a symbol (other than bit symbols) in another module is to be referenced in this module

.public

Declares to the optimizing linker that the symbol described in the operand field is a symbol to be referenced from another module.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.public	*label-name*[, *absolute-expression*]	[; *comment*]

[Function]

- The .public directive declares to the optimizing linker that the symbol described in the operand field is a symbol to be referenced from another module.

[Use]

- When defining a symbol to be referenced from another module, the .public directive must be used to declare the symbol as an external definition.

[Description]

- A label with the same name as the one specified by the first operand is declared as an external label[Note].
  Note that if a second operand was specified, this specifies the size of the data indicated by that label. However, specifications of size are ignored (although including them has been allowed to retain compatibility with CX).

  Note This is an external symbol (symbol with a GLOBAL binding class).

- Although this directive does not function any differently than an ".extern" directive in that it declares an external label, if this directive is used to declare a label with a definition in the specified file as an external label, use the ".extern" directive to declare labels without definitions in the specified file as external labels.
- The .public directive may be described anywhere in a source program.
- The ".public" directive can only define one symbol per line.
- When the symbol(s) to be described in the operand field isn't defined within the same module, an warning is output. When the symbol(s) isn't defined in any file, it will cause an error during linking.
- The following symbols cannot be used as the operand of the .public directive:

(1) Symbol defined with the .set directive

(2) Externally referenced symbol (symbol defined with the .extern directive)

(3) Section name

(4) Module name

(5) Macro name

(6) Undefined symbol in the source program

[Example]

- Module 1

```
        .public A1              ; (1)
        .extern B1


A1:
        .db2    0x10

        .cseg   text
        jr      B1
```

- Module 2

```
        .public B1              ; (2)
        .extern A1
        .cseg   text
B1:
        mov     A1, r12
```

(1) This .public directive declares that symbol "A1" is to be referenced from other modules.

(2) This .public directive declares that symbol "B1" is to be referenced from another module.

.extern

Declares to the optimizing linker that a symbol (other than bit symbols) in another module is to be referenced in this module.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.extern	*label-name*[, *absolute-expression*]	[; *comment*]

[Function]

- The .extern directive declares to the optimizing linker that a symbol in another module is to be referenced in this module.

[Use]

- When referencing a symbol defined in another module, the .extern directive must be used to declare the symbol as an external reference.

[Description]

- A label with the same name as the one specified by the first operand is declared as an external label[Note].
  Note that if a second operand was specified, this specifies the size of the data indicated by that label. However, specifications of size are ignored (although including them has been allowed to retain compatibility with CX).

  Note This is an external symbol (symbol with a GLOBAL binding class).

- Although this directive does not function any differently than an ".public" directive in that it declares an external label, if this directive is used to declare a label without a definition in the specified file as an external label, use the ".public" directive to declare labels with definitions in the specified file as external labels.
- The .extern directive may be described anywhere in a source program.
- The ".extern" directive can only define one symbol per line.
- No error is output even if a symbol declared with the .extern directive is not referenced in the module.
- An error will occur if the symbol specified as the first operand has already been defined or declared with a .public or .extern directive in the given module. The symbol name is output in the error message.
- Names of macros cannot be used as the first operand.

4.2.7 Macro directives

When describing a source it is inefficient to have to describe for each series of high usage frequency instruction groups. This is also the source of increased errors.

Via macro directives, using macro functions it becomes unnecessary to describe many times to the same kind of instruction group series, and coding efficiency can be improved.

Macro basic functions are in substitution of a series of statements.

The following macro directives are available.

Table 4-13. Macro Directives

Directive	Overview
.macro	Executes a macro definition by assigning the macro name specified in the symbol field to a series of statements described between .macro directive and the .endm directive.
.local	The specified string is declared as a local symbol that will be replaced as a specific identifier.
.rept	Tells the assembler to repeatedly expand a series of statements described between .rept directive and the .endm directive the number of times equivalent to the value of the expression specified in the operand field.
.irp	Tells the assembler to repeatedly expand a series of statements described between .irp directive and the .endm directive the number of times equivalent to the number of actual parameters while replacing the formal parameter with the actual parameters (from the left, the order) specified in the operand field.
.exitm	This directive skips the repetitive assembly of the .irp and .rept directives enclosing this directive at the innermost position.
.exitma	This directive skips the repetitive assembly of the irp and .rept directives enclosing this directive at the outermost position.
.endm	Instructs the assembler to terminate the execution of a series of statements defined as the functions of the macro.

.macro

Executes a macro definition by assigning the macro name specified in the symbol field to a series of statements described between .macro directive and the .endm directive.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
macro-name	.macro	[*formal-parameter*[, ...]]	[; *comment*]
	:		
	Macro body		
	:		
	.endm		[; *comment*]

[Function]

- The .macro directive executes a macro definition by assigning the macro name specified in the symbol field to a series of statements (called a macro body) described between this directive and the .endm directive.

[Use]

- Define a series of frequently used statements in the source program with a macro name. After its definition only describe the defined macro name, and the macro body corresponding to the macro name is expanded.

[Description]

- If the .endm directive corresponding to .macro directive does not exist, the CC-RH outputs the message.
- For the macro name to be described in the symbol field, see the conventions of symbol description in "(2) Symbol".
- To reference a macro, describe the defined macro name in the mnemonic field.
- For the formal parameter(s) to be described in the operand field, the same rules as the conventions of symbol description will apply.
- Formal parameters are valid only within the macro body.
- An error occurs if any reserved word is described as a formal parameter. However, if a user-defined symbol is described, its recognition as a formal parameter will take precedence.
- The number of formal parameters must be the same as the number of actual parameters. If a shortage of actual parameters, the CC-RH outputs the error message.
- The theoretical maximum number of formal parameters is 4,294,967,294 (i.e. 0xFFFFFFFE). The actual number that can be used depends on the amount of memory, however.
- A name or label defined within the macro body if declared with the .local directive becomes effective with respect to one-time macro expansion.
- The number of macros that can be defined within a single source module is not specifically limited. In other words, macros may be defined as long as there is memory space available.
- Formal parameter definition lines, reference lines, and symbol names are not output to a cross-reference list.
- Two or more sections must not be defined in a macro body. If defined, an error will be output.
- An error will be output if there are extra formal parameters that are not referenced in the macro body.
- If an undefined macro is called in a macro body, the CC-RH outputs the message then stops assembling.
- If a currently defined macro is called in a macro body, the CC-RH outputs the message then stops assembling.
- If a parameter defined by a label or directive is specified for a formal parameter, the CC-RH outputs the message and stops assembling.

- The only actual parameters that can be specified in the macro call are label names, symbol names, numbers, registers, and instruction mnemonics.

  If a label expression (LABEL-1), addressing-method specification label (#LABEL), or base register specification ([gp]) or the like is specified, then a message will be output depending on the actual parameter specified, and assembly will halt.

- A line of a sentence can be designated in the macro-body. Such as operand can't designate the part of the sentence. If operand has a macro call, performs a label reference is undefined macro name, or the CC-RH outputs the message then stops assembling.
- An error will be output if a macro is defined in the macro body of a macro definition, but processing will continue (the content up to the corresponding ".endm" directive is ignored). Referencing a macro name will cause a definition error.

[Example]

```
ADMAC   .macro  PARA1, PARA2    ; (1)
        mov     PARA1, r12
        add     PARA2, r12
        .endm                   ; (2)

        ADMAC   0x10, 0x20      ; (3)
```

(1) A macro is defined by specifying macro name "ADMAC" and two formal parameters "PARA1" and "PARA2".

(2) This directive indicates the end of the macro definition.

(3) Macro "ADMAC" is referenced.

.local

The specified string is declared as a local symbol that will be replaced as a specific identifier.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	.local	*symbol-name*[, ...]	[; *comment*]

[Function]

- The .local directive declares a specified symbol name as a local symbol that will be replaced as an assembler-specific symbol.

[Use]

- If a macro that defines a symbol within the macro body is referenced more than once, the assembler will output a double definition error for the symbol.
  By using the .local directive, you can reference (or call) a macro, which defines symbol(s) within the macro body, more than once.

[Description]

- The theoretical maximum number of symbol names is 4,294,967,294 (i.e. 0xFFFFFFFE). The actual number that can be used depends on the amount of memory, however.
- Specifying 4,294,967,294 or more local symbols as formal parameters to ".local" quasi directives will cause the following error message to be output, and the assembly will halt.

```
F0550514 : Paramater table overflow.
```

- Local symbol names generated by the assembler are generated in the range of .??00000000 to .??FFFFFFFF.
- Only an undefined symbol or a symbol that has been declared as a local symbol can be declared as a local symbol.
- A specific symbol that will replace the specified symbol name is generated for each declaration.
- To make the declared symbol valid, the symbol should be defined as a label.
- The symbol name declared as a local symbol cannot be defined for any purpose other than a label.

[Example]

```
m1      .macro  x
        .local  a, b
        a:      .dw     a
        b:      .dw     x
.endm
m1      10
m1      20
```

The expansion is as follows.

```
.??00000000:    .dw     .??00000000
.??00000001:    .dw     10
.??00000002:    .dw     .??00000002
.??00000003:    .dw     20
```

.rept

Tells the assembler to repeatedly expand a series of statements described between this directive and the .endm directive the number of times equivalent to the value of the expression specified in the operand field.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.rept	*absolute-expression*	[; *comment*]
	:		
	.endm		[; *comment*]

[Function]

- The .rept directive tells the assembler to repeatedly expand a series of statements described between this directive and the .endm directive (called the REPT-ENDM block) the number of times equivalent to the value of the expression specified in the operand field.

[Use]

- Use the .rept and .endm directives to describe a series of statements repeatedly in a source program.

[Description]

- An error occurs if the .rept directive is not paired with the .endm directive.
- If the .exitm directive appears in the REPT-ENDM block, subsequent expansion of the REPT-ENDM block by the assembler is terminated.
- Assembly control instructions may be described in the REPT-ENDM block.
- Macro definitions cannot be described in the REPT-ENDM block.
- The value is evaluated as a 32-bit signed integer.
- If there is no arrangement of statements (block), nothing is executed.
- If the result of evaluating the expression is negative, the CC-RH outputs the message then stops assembling.
- An error will be output if a macro is defined in the macro body of a macro definition, and processing will continue, without performing expansion.

[Example]

```
.cseg   text
        ; REPT-ENDM block
.rept   3               ; (1)
        nop
        ; Source text
.endm                   ; (2)
```

(1) This .rept directive tells the assembler to expand the REPT-ENDM block three consecutive times.

(2) This directive indicates the end of the REPT-ENDM block.

.irp

Tells the assembler to repeatedly expand a series of statements described between .irp directive and the .endm directive the number of times equivalent to the number of actual parameters while replacing the formal parameter with the actual parameters (from the left, the order) specified in the operand field.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.irp	*formal-parameter*[*actual-parameter*[, ...]]	[; *comment*]
	:		
	.endm		[; *comment*]

[Function]

- The .irp directive tells the assembler to repeatedly expand a series of statements described between this directive and the .endm directive (called the IRP-ENDM block) the number of times equivalent to the number of actual parameters while replacing the formal parameter with the actual parameters (from the left, the order) specified in the operand field.

[Use]

- Use the .irp and .endm directives to describe a series of statements, only some of which become variables, repeatedly in a source program.

[Description]

- If the .endm directive corresponding to .irp directive does not exist, the CC-RH outputs the message.
- If the .exitm directive appears in the IRP-ENDM block, subsequent expansion of the IRP-ENDM block by the assembler is terminated.
- Macro definitions cannot be described in the IRP-ENDM block.
- Assembly control instructions may be described in the IRP-ENDM block.
- The theoretical maximum number of actual parameters is 4,294,967,294 (i.e. 0xFFFFFFFE). The actual number that can be used depends on the amount of memory, however.
- If the same parameter name is specified for a formal parameter and an actual parameter, the CC-RH outputs the message and stops assembling.
- If a parameter defined by a label or other directive is specified for a formal parameter and an actual parameter, the CC-RH outputs the message and stops assembling.
- An error will be output if a macro is defined in the macro body of a macro definition, and processing will continue, without performing expansion.

[Example]

```
.cseg   text

.irp    PARA 0xA, 0xB, 0xC              ; (1)
    ; IRP-ENDM block
        add     PARA, r12
        mov     r11, r12
.endm                                   ; (2)
    ; Source text
```

(1) The formal parameter is "PARA" and the actual parameters are the following three: "0xA", "0xB", and "0xC".
This .irp directive tells the assembler to expand the IRP-ENDM block three times (i.e., the number of actual parameters) while replacing the formal parameter "PARA" with the actual parameters "0xA", "0xB", and "0xC"

(2) This directive indicates the end of the IRP-ENDM block.

.exitm

This directive skips the repetitive assembly of the .irp and .rept directives enclosing this directive at the innermost position.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.exitm		[; *comment*]

[Function]

- This directive skips the repetitive assembly of the .irp and .rept directives enclosing this directive at the innermost position.

[Description]

- If this directive is not enclosed by .irp and .rept directives, the CC-RH outputs the message then stops assembling.

.exitma

This directive skips the repetitive assembly of the irp and .rept directives enclosing this directive at the outermost position.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
[*label*:]	.exitma		[; *comment*]

[Function]

- This directive skips the repetitive assembly of the irp and .rept directives enclosing this directive at the outermost position.

[Description]

- If this directive is not enclosed by .irp and .rept directives, the CC-RH outputs the message then stops assembling.

.endm

Instructs the assembler to terminate the execution of a series of statements defined as the functions of the macro.

[Syntax]

Symbol field	Mnemonic field	Operand field	Comment field
	.endm		[; *comment*]

[Function]

- The .endm directive instructs the assembler to terminate the execution of a series of statements defined as the functions of the macro.

[Use]

- The .endm directive must always be described at the end of a series of statements following the .macro, .rept, and/or the .irp directives.

[Description]

- A series of statements described between the .macro directive and .endm directive becomes a macro body.
- A series of statements described between the .rept directive and .endm directive becomes a REPT-ENDM block.
- A series of statements described between the .irp directive and .endm directive becomes an IRP-ENDM block.
- If the .macro, .rept, or .irp directive corresponding to this directive does not exist, the CC-RH outputs the message then stops assembling.

[Example]

(1) MACRO-ENDM

```
ADMAC   .macro  PARA1, PARA2
                mov     A, #PARA1
                add     A, #PARA2
        .endm
```

(2) REPT-ENDM

```
.cseg   text
  :
.rept   3
        inc     B
        DEC     C
.endm
```

(3) IRP-ENDM

```
.cseg   text
  :
.irp    PARA, <1, 2, 3>
        add     A, #PARA
        mov     [DE], A
.endm
```

4.3 Control Instructions

Control Instructions provide detailed instructions for assembler operation.

4.3.1 Outline

Control instructions provide detailed instructions for assembler operation and so are written in the source.

Control instructions do not become the target of object code generation.

Control instruction categories are displayed below.

Table 4-14. Control Instruction List

Control Instruction Type	Control Instruction
Assembler control instructions	REG_MODE, NOMACRO, MACRO, DATA, SDATA, NOWARNING, WARNING
File input control instructions	INCLUDE, BINCLUDE
Conditional assembly control instructions	IFDEF, IFNDEF, IF, IFN, ELSEIF, ELSEIFN, ELSE, ENDIF

As with directives, control instructions are specified in the source.

4.3.2 Assembler control instructions

The assembler control instruction can be used to control the processing performed by the assembler.

The following assembler control instructions are available.

Table 4-15. Assembler Control Instructions

Control Instruction	Overview
REG_MODE	Outputs a register mode information section
NOMACRO	Does not expand the subsequent instructions
MACRO	Cancels the specification made with the NOMACRO directive
DATA	Assumes that external data having symbol name extern_symbol has been allocated to the data or bss attribute section, and expands the instructions which reference that data
SDATA	Assumes that external data having symbol name extern_symbol has been allocated to the sdata or sbss attribute section, and dose not expand the instructions which reference that data
NOWARNING	Does not output warning messages
WARNING	Output warning messages

REG_MODE

A register mode information section is output.

[Syntax]

```
[Δ]$[Δ]REG_MODE[Δ]specify-register-mode[Δ][;comment]
```

[Function]

- A register mode information section is output into the object module file generated by the assembler.

[Description]

- Specify the register mode as "22" (indicating register mode 22); "32" (indicating register mode 32); or "common" (indicating universal register mode).
- A register mode information section stores information about the number of working registers and register-variable registers used by the compiler. It is set in the object module file via this control instruction.
- If register mode 22 is used, then there are 5 working registers and 5 register-variable registers; and if register mode 32 is used, then there are 10 of each.
- If register mode 32 is used, a register mode information section is not output into the object module file generated by the assembler.
- If the register mode of this control instruction differs from the register mode specified via options, then CC-RH will output a warning, and ignore the register mode specified via the options.
- If the register modes specified by this control instruction span multiple lines, and the specified register modes are different, then the first register-mode specification will be valid. CC-RH will output warnings for the different register-mode specifications, and ignore those specifications.

NOMACRO

Does not expand the subsequent instructions.

[Syntax]

```
[Δ]$[Δ]NOMACRO[Δ][;comment]
```

[Function]

- Does not expand the subsequent instructions, other than the setfcond/jcond/jmp/cmovcond/sasfcond instructions.

MACRO

Cancels the specification made with the NOMACRO directive.

[Syntax]

```
[Δ]$[Δ]MACRO[Δ][;comment]
```

[Function]

- Cancels the specification made with the NOMACRO directive for the subsequent instructions.

DATA

Assumes that external data having symbol name extern_symbol has been allocated to the data or bss attribute section, and expands the instructions which reference that data.

[Syntax]

```
[Δ]$[Δ]DATA[Δ]symbol-name[Δ][;comment]
```

[Function]

- Assumes that external data having symbol name extern_symbol has been allocated to the data or bss attribute section, and expands the instructions which reference that data.
- This format is used when a variable for which "data" is specified in #pragma section is externally referenced by an assembler source file.

SDATA

Assumes that external data having symbol name extern_symbol has been allocated to the sdata or sbss attribute section, and dose not expand the instructions which reference that data.

[Syntax]

```
[Δ]$[Δ]SDATA[Δ]symbol-name[Δ][;comment]
```

[Function]

- Assumes that external data having symbol name extern_symbol has been allocated to the sdata or sbss attribute section, and does not expand the instructions which reference that data.
- This format is used when a variable for which "sdata" is specified in #pragma section is externally referenced by an assembler source file.

NOWARNING

Does not output warning messages.

[Syntax]

```
[Δ]$[Δ]NOWARNING[Δ][;comment]
```

[Function]

- Does not output warning messages for the subsequent instructions.

WARNING

Output warning messages.

[Syntax]

```
[Δ]$[Δ]WARNING[Δ][;comment]
```

[Function]

- Output warning messages for the subsequent instructions.

4.3.3 File input control instructions

Using the file input control instruction, the CC-RH can input an assembler source file or binary file to a specified position.

The following file input control instructions are available.

Table 4-16. File Input Control Instructions

Control Instruction	Overview
INCLUDE	Quotes a series of statements from another source module file
BINCLUDE	Inputs a binary file

INCLUDE

Quote a series of statements from another source module file.

[Syntax]

```
[Δ]$[Δ]INCLUDE[Δ]([Δ]file-name[Δ])[Δ][;comment]
```

[Function]

- The INCLUDE control instruction tells the assembler to insert and expand the contents of a specified file beginning on a specified line in the source program for assembly.

[Use]

- A relatively large group of statements that may be shared by two or more source modules should be combined into a single file as an INCLUDE file.
  If the group of statements must be used in each source module, specify the filename of the required INCLUDE file with the INCLUDE control instruction.
  With this control instruction, you can greatly reduce time and labor in describing source modules.

[Description]

- The INCLUDE control instruction can only be described in ordinary source programs.
- The search pass of an INCLUDE file can be specified with the option (-I).
- The assembler searches INCLUDE file read paths in the following sequence:

(1) Folder specified by the option (-I)

(2) Standard include file folder

(3) Folder in which the source file exists

(4) Folder containing the (original) C source file

(5) Currently folder

- The INCLUDE file can do nesting (the term "nesting" here refers to the specification of one or more other INCLUDE files in an INCLUDE file).
- The maximum nesting level for include files is 4,294,967,294 (=0xFFFFFFFE) (theoretical value). The actual number that can be used depends on the amount of memory, however.
- If the specified INCLUDE file cannot be opened, the CC-RH outputs the message and stops assembling.
- If an include file contains a block from start to finish, such as a section definition directive, macro definition directive, or conditional assembly control instruction, then it must be closed with the corresponding code. If it is not so closed, then an error will be output, and assembly will continue assuming the include file is closed.
- Section definition directive, macro definition directives, and conditional assembly control instructions that are not targets for assembly are not checked.

BINCLUDE

Inputs a binary file.

[Syntax]

```
[Δ]$[Δ]BINCLUDE[Δ]([Δ]file-name[Δ])[Δ][;comment]
```

[Function]

- Assumes the contents of the binary file specified by the operand to be the result of assembling the source file at the position of this control instruction.

[Description]

- The search pass of an INCLUDE file can be specified with the option (-I).
- The assembler searches INCLUDE file read paths in the following sequence:

(1) Folder specified by the option (-I)

(2) Standard include file folder

(3) Folder in which the source file exists

(4) Folder containing the (original) C source file

(5) Currently folder

- This control instruction handles the entire contents of the binary files. When a relocatable file is specified, this control instruction handles files configured in ELF format. Note that it is not just the contents of the .text selection, etc. that are handled.
- If a non-existent file is specified, the CC-RH outputs the message then stops assembling.

4.3.4 Conditional assembly control instructions

Using conditional assembly control instruction, the CC-RH can control the range of assembly according to the result of evaluating a conditional expression.

The following conditional assembly control instructions are available.

Table 4-17. Conditional Assembly Control Instructions

Control Instruction	Overview
IFDEF	Control based on symbol (assembly performed when the symbol is defined)
IFNDEF	Control based on symbol (assembly performed when the symbol is not defined)
IF	Control based on absolute expression (assembly performed when the value is true)
IFN	Control based on absolute expression (assembly performed when the value is false)
ELSEIF	Control based on absolute expression (assembly performed when the value is true)
ELSEIFN	Control based on absolute expression (assembly performed when the value is false)
ELSE	Control based on absolute expression/symbol
ENDIF	End of control range

The maximum number of nest level of the conditional assembly control instruction is 4,294,967,294 (=0xFFFFFFFE) (theoretical value). The actual number that can be used depends on the amount of memory, however.

IFDEF

Control based on symbol (assembly performed when the symbol is defined).

[Syntax]

```
[Δ]$[Δ]IFDEF[Δ]switch-name[Δ][;comment]
```

[Function]

- If the switch name specified by the operand is defined.

(a) If this control instruction and the corresponding ELSEIF, ELSEIFN, or ELSE control instruction exist, assembles the block enclosed within this control instruction and the corresponding control instruction.

(b) If none of the corresponding control instruction detailed above exist, assembles the block enclosed within this control instruction and the corresponding ENDIF control instruction.

- If the specified switch name is not defined.
  Skips to the ELSEIF, ELSEIFN, ELSE, or ENDIF control instruction corresponding to this control instruction.

[Use]

- With these conditional assembly control instructions, source statements subject to assembly can be changed without major modifications to the source program.
- If a statement for debugging that becomes necessary only during the program development is described in a source program, whether or not the debugging statement should be assembled (translated into machine language) can be specified by setting switches for conditional assembly.

[Description]

- This control instruction can be placed in an ordinary source program.
- The rules of describing switch names are the same as the conventions of symbol description (for details, see "(2) Symbol").
- Switch names can overlap with user-defined symbols other than reserved words. Note, however, that overlapping between switch names is checked.
- Switch names are not output to the assembly list file's symbol-list information or cross-reference information.

IFNDEF

Control based on symbol (assembly performed when the symbol is not defined).

[Syntax]

```
[Δ]$[Δ]IFNDEF[Δ]switch-name[Δ][;comment]
```

[Function]

- If the switch name specified by the operand is defined.
  Skips to the ELSEIF, ELSEIFN, ELSE, or ENDIF control instruction corresponding to this control instruction.

- If the specified switch name is not defined.

(a) If this control instruction and the corresponding ELSEIF, ELSEIFN, or ELSE control instruction exist, assembles the block enclosed within this control instruction and the corresponding control instruction.

(b) If none of the corresponding control instruction detailed above exist, assembles the block enclosed within this control instruction and the corresponding ENDIF control instruction.

[Use]

- With these conditional assembly control instructions, source statements subject to assembly can be changed without major modifications to the source program.
- If a statement for debugging that becomes necessary only during the program development is described in a source program, whether or not the debugging statement should be assembled (translated into machine language) can be specified by setting switches for conditional assembly.

[Description]

- This control instruction can be placed in an ordinary source program.
- The rules of describing switch names are the same as the conventions of symbol description (for details, see "(2) Symbol").
- Switch names can overlap with user-defined symbols other than reserved words. Note, however, that overlapping between switch names is checked.
- Switch names are not output to the assembly list file's symbol-list information or cross-reference information.

IF

Control based on absolute expression (assembly performed when the value is true).

[Syntax]

```
[Δ]$[Δ]IF[Δ]absolute-expression[Δ][;comment]
```

[Function]

- If the absolute expression specified by the operand is evaluated as being true (≠ 0).

  (a) If this control instruction and the corresponding ELSEIF, ELSEIFN, or ELSE control instruction exist, assembles the block enclosed within this control instruction and the corresponding control instruction.

  (b) If none of the corresponding control instruction detailed above exist, assembles the block enclosed within this control instruction and the corresponding ENDIF control instruction.

- If the absolute expression is evaluated as being false (= 0).
  Skips to the ELSEIF, ELSEIFN, ELSE, or ENDIF control instruction corresponding to this control instruction.

[Use]

- With these conditional assembly control instructions, source statements subject to assembly can be changed without major modifications to the source program.
- If a statement for debugging that becomes necessary only during the program development is described in a source program, whether or not the debugging statement should be assembled (translated into machine language) can be specified by setting switches for conditional assembly.

[Description]

- This control instruction can be placed in an ordinary source program.
- Absolute expressions are evaluated as 32-bit signed integers.

IFN

Control based on absolute expression (assembly performed when the value is false).

[Syntax]

```
[Δ]$[Δ]IFN[Δ]absolute-expression[Δ][;comment]
```

[Function]

- If the absolute expression specified by the operand is evaluated as being true (≠ 0).
  Skips to the ELSEIF, ELSEIFN, ELSE, or ENDIF control instruction corresponding to this control instruction.

- If the absolute expression is evaluated as being false (= 0).

(a) If this control instruction and the corresponding ELSEIF, ELSEIFN, or ELSE control instruction exist, assembles the block enclosed within this control instruction and the corresponding control instruction.

(b) If none of the corresponding control instruction detailed above exist, assembles the block enclosed within this control instruction and the corresponding ENDIF control instruction.

[Use]

- With these conditional assembly control instructions, source statements subject to assembly can be changed without major modifications to the source program.
- If a statement for debugging that becomes necessary only during the program development is described in a source program, whether or not the debugging statement should be assembled (translated into machine language) can be specified by setting switches for conditional assembly.

[Description]

- This control instruction can be placed in an ordinary source program.
- Absolute expressions are evaluated as 32-bit signed integers.

ELSEIF

Control based on absolute expression (assembly performed when the value is true).

[Syntax]

```
[Δ]$[Δ]ELSEIF[Δ]absolute-expression[Δ][;comment]
```

[Function]

- If the absolute expression specified by the operand is evaluated as being true (≠ 0).

(a) If this control instruction and the corresponding ELSEIF, ELSEIFN, or ELSE control instruction exist, assembles the block enclosed within this control instruction and the corresponding control instruction.

(b) If none of the corresponding control instruction detailed above exist, assembles the block enclosed within this control instruction and the corresponding ENDIF control instruction.

- If the absolute expression is evaluated as being false (= 0).
  Skips to the ELSEIF, ELSEIFN, ELSE, or ENDIF control instruction corresponding to this control instruction.

[Use]

- With these conditional assembly control instructions, source statements subject to assembly can be changed without major modifications to the source program.
- If a statement for debugging that becomes necessary only during the program development is described in a source program, whether or not the debugging statement should be assembled (translated into machine language) can be specified by setting switches for conditional assembly.

[Description]

- This control instruction can be placed in an ordinary source program.
- Absolute expressions are evaluated as 32-bit signed integers.

ELSEIFN

Control based on absolute expression (assembly performed when the value is false).

[Syntax]

```
[Δ]$[Δ]ELSEIFN[Δ]absolute-expression[Δ][;comment]
```

[Function]

- If the absolute expression specified by the operand is evaluated as being true (≠ 0).
  Skips to the ELSEIF, ELSEIFN, ELSE, or ENDIF control instruction corresponding to this control instruction.

- If the absolute expression is evaluated as being false (= 0).

(a) If this control instruction and the corresponding ELSEIF, ELSEIFN, or ELSE control instruction exist, assembles the block enclosed within this control instruction and the corresponding control instruction.

(b) If none of the corresponding control instruction detailed above exist, assembles the block enclosed within this control instruction and the corresponding ENDIF control instruction.

[Use]

- With these conditional assembly control instructions, source statements subject to assembly can be changed without major modifications to the source program.
- If a statement for debugging that becomes necessary only during the program development is described in a source program, whether or not the debugging statement should be assembled (translated into machine language) can be specified by setting switches for conditional assembly.

[Description]

- This control instruction can be placed in an ordinary source program.
- Absolute expressions are evaluated as 32-bit signed integers.

ELSE

Control based on absolute expression/symbol.

[Syntax]

```
[Δ]$[Δ]ELSE[Δ]absolute-expression[Δ][;comment]
```

[Function]

- If the specified switch name is not defined by the IFDEF control instruction, if the absolute expression of the IF, or ELSEIF control instruction is evaluated as being false (= 0), or if the absolute expression of the IFN, or ELSEIFN control instruction is evaluated as being true (≠ 0), assembles the arrangement of statements (block) enclosed within this control instruction and the corresponding ENDIFcontrol instruction.

[Use]

- With these conditional assembly control instructions, source statements subject to assembly can be changed without major modifications to the source program.
- If a statement for debugging that becomes necessary only during the program development is described in a source program, whether or not the debugging statement should be assembled (translated into machine language) can be specified by setting switches for conditional assembly.

[Description]

- This control instruction can be placed in an ordinary source program.

ENDIF

End of control range.

[Syntax]

```
[Δ]$[Δ]ENDIF[Δ]absolute-expression[Δ][;comment]
```

[Function]

Indicates the end of the control range of a conditional assembly control instruction.

[Use]

- With these conditional assembly control instructions, source statements subject to assembly can be changed without major modifications to the source program.
- If a statement for debugging that becomes necessary only during the program development is described in a source program, whether or not the debugging statement should be assembled (translated into machine language) can be specified by setting switches for conditional assembly.

[Description]

- This control instruction can be placed in an ordinary source program.

4.4 Macro

This section lainshe hthe cro function.

This is very convenient function to describe serial instruction group for number of times in the program.

4.4.1 Outline

This macro function is very convenient function to describe serial instruction group for number of times in the program.

Macro function is the function that is deployed at the location where serial instruction group defined as macro body is referred by macros as per .macro, .endm directives.

Macro differs from subroutine as it is used to improve description of the source.

Macro and subroutine has features respectively as follows. Use them effectively according to the respective purposes.

- Subroutine

  Process required many times in program is described as one subroutine. Subroutine is converted in machine language only once by assembler.

  Subroutine/call instruction (generally instruction for argument setting is required before and after it) is described only in subroutine reference. Consequently, memory of program can be used effectively by using subroutine.

  It is possible to draw structure of program by executing subroutine for process collected serially in program (Because program is structured, entire program structure can be easily understood as well setting of the program also becomes easy.).

- Macro

  Basic function of macro is to replace instruction group.

  Serial instruction group defined as macro body by .macro, .endm directives are deployed in that location at the time of referring macro. Assembler deploys macro/body that detects macro reference and converts the instruction group to machine language while replacing temporary parameter of macro/body to actual parameter at the time of reference.

  Macro can describe a parameter.

  For example, when process sequence is the same but data described in operand is different, macro is defined by assigning temporary parameter in that data. When referring the macro, by describing macro name and actual parameter, handling of various instruction groups whose dercription is different in some parts only is possible.

Subroutine technique is used to improve efficiency of coding for macro to use to draw structure of program and reducing memory size.

4.4.2 Usage of macro

A macro is described by registering a pattern with a set sequence and by using this pattern. A macro is defined by the user. A macro is defined as follows. The macro body is enclosed by ".macro" and ".endm".

```
PUSHMAC .macro  REG             ;The following two statements constitute the macro body.
        add     -4, sp
        st.w    REG, 0x0[sp]
.endm
```

If the following description is made after the above definition has been made, the macro is replaced by a code that "stores r19 in the stack".

```
PUSHMAC r19
```

In other words, the macro is expanded into the following codes.

```
add     -4, sp
st.w    r19, 0x0[sp]
```

4.4.3 Macro operator

This section describes the combination symbols "~" and "$", which are used to link strings in macros.

(1) ~ (Concatenation)

- The concatenation "~" concatenates one character or one character string to another within a macro body. At macro expansion time, the character or character string on the left of the concatenation is concatenated to the character or character string on the right of the sign. The "~" itself disappears after concatenating the strings.
- The symbols before and after the combination symbol "~" in the symbols of a macro definition can be recognized as formal parameters or local symbols, and combination symbols can also be used as delimiter symbols. At macro expansion time, strings before and after the "~" in the symbol are evaluated as the local symbols and formal parameters, and concatenated into single symbols.
- The character "~" can only be used as a combination symbol in a macro definition.
- The "~" in a character string and comment is simply handled as data.
- Two "~" signs in succession are handled as a single "~" sign.

Examples 1.

```
abc     .macro  x
        abc~x:  mov     r10, r20
                sub def~x, r20
.endm
abc STU
```

```
[Development result]
abcSTU: mov     r10, r20
        sub     defSTU, r20
```

2.

```
abc     .macro  x, xy
        a_~xy:  mov     r10, r20
        a_~x~y: mov     r20, r10
.endm
abc necel, STU
```

```
[Development result]
a_STU:  mov     r10, r20
a_stuy: mov     r20, r10
```

3.

```
abc     .macro  x, xy
        ~ab:    mov r10, r20
.endm
abc stu, STU
```

```
[Development result]
ab:     mov     r10, r20
```

(2) $ (Dollar symbol)

If a symbol prefixed with a dollar symbol ($) is specified as an actual argument for a macro call, the assembler assumes the symbol to be specified as an actual argument. If, however, an identifier other than a symbol or an undefined symbol name is specified immediately after the dollar symbol ($), the as850 outputs the message then stops assembling.

Example

```
mac1    .macro  x
        mov     x, r10
.endm
mac2    .macro
value   .set    10
        mac1    value
        mac1    $value
.endm
mac2
```

4.5 Reserved Words

The assembler has reserved words. Reserve word cannot be used in symbol, label, section name, macro name. If a reserved word is specified, the CC-RH outputs the message and stops assembling. Reserve word doesn't distinguish between uppercase and lowercase.

The reserved words are as follows.

- Instructions (such as add, sub, and mov)
- Directives
- Control instructions
- Register names, Internal register name
- GHS reserved sections ("_GHS", ".ghs", and section names starting with ".__ghs")

4.6 Assembler Generated Symbols

The following is a list of symbols generated by the assembler for use in internal processing.

Symbols with the same names as the symbols below cannot be used.

The assembler does not output object files for symbols starting with a period ("."), treating these as symbols for internal processing.

Table 4-18. Assembler Generated Symbols

Symbol Name	Explanation
.??00000000 to .??FFFFFFFF	.local directive generation local symbols
.LMn_n (n:0 - 4294967294)	Example : .LM0_1

4.7 Instruction Set

This section explains the instruction set supported by the CC-RH.

(1) Description of symbols

Next table lists the meanings of the symbols used further.

Table 4-19. Meaning of Symbols

Symbols	Meaning
CMD	Instruction
CMDi	Instruction(andi, ori, or xori)
reg, reg1, reg2	Register
r0, R0	Zero register
R1	Assembler-reserved register
gp	Global pointer (r4)
ep	Element pointer (r30)
[reg]	Base register
disp	Displacement (Displacement from the address) 32 bits unless otherwise stated.
disp*n*	*n*-bit displacement
imm	Immediate 32 bits unless otherwise stated.
imm*n*	*n*-bit immediate
bit#3	3-bit data for bit number specification
cc#3	3-bit data for specifying CC0 to CC7 (bits 24 to 31) of the FPSR floating-point system register
#label	Absolute address reference of label
label	Offset reference of label in section or PC offset reference
$label	gp offset reference of label
!label	Absolute address reference of label (without instruction expansion)
%label	Offset reference of label within the section (no instruction expansion) or offset reference of ep
HIGHW(*value*)	Higher 16 bits of *value*
LOWW(*value*)	Lower 16 bits of *value*
HIGHW1(*value*)	Higher 16 bits of *value* + bit value[Note] of bit number 15 of *value*
HIGH(*value*)	Upper 8 bits of the lower 16 bits of *value*
LOW(*value*)	Lower 8 bits of *value*
addr	Address
PC	Program counter
PSW	Program status word
regID	System register number (0 to 31)
vector	Trap vector (0 to 31)
BITIO	Peripheral I/O register (for 1-bit manipulation only)

Note The bit number 0 is LSB (Least Significant Bit).

(2) Operand

This section describes the description format of operand in assembler. In assembler, register, constant, symbol, label reference, and expression that composes of constant, symbol, label reference, operator and parentheses can be specified as the operands for instruction, and directives.

(a) Register

The registers that can be specified with the assembler are listed below.[Note]

r0, zero, r1, r2, hp, r3, sp, r4, gp, r5, tp, r6, r7, r8, r9, r10, r11, r12, r13, r14, r15, r16, r17, r18, r19, r20, r21, r22, r23, r24, r25, r26, r27, r28, r29, r30, ep, r31, lp

Note For the ldsr and stsr instructions, the PSW, and system registers are specified by using the numbers. Further, in assembler, PC cannot be specified as an operand.

r0 and zero (Zero register), r2 and hp (Handler stack pointer), r3 and sp (Stack pointer), r4 and gp (Global pointer), r5 and tp (Text pointer), r30 and ep (Element pointer), r31 and lp (Link pointer) shows the same register.

(b) r0

r0 is the register which normally contains 0 value. This register does not substitute the result of an operation even if used as a destination register. When r0 is specified as a destination register, the assembler outputs the following message[Note], and then continues assembling.

Note Output of this message can be suppressed by specifying the warning message suppression option (-Xno_warning) upon starting the assembler.

```
mov     0x10, r0
    ↓
W0550013: register r1 used as destination register.
```

(c) r1

The assembler-reserved register (r1) is used as a temporary register when instruction expansion is performed using the assembler. If r1 is specified as a source or destination register, the assembler outputs the following message[Note], then continues assembling.

Note Output of this message can be suppressed by specifying the warning message suppression option (-Xno_warning) upon starting the assembler.

```
mov     0x10, r1
    ↓
W0550013: register r1 used as destination register.
```

```
mov     r1, r10
    ↓
W0550013: register r1 used as source register.
```

(d) Constants

As the constituents of the absolute expressions or relative expressions that can be used to specify the operands of the instructions and pseudo-instruction in the assembler, integer constants and character constants can be used.

Floating-point constants can be used to specify the operand of the .float pseudo-instruction.

(e) Symbols

The assembler supports the use of symbols as the constituents of the absolute expressions or relative expressions that can be used to specify the operands of instructions and directives.

(f) Label reference

In assembler, label reference can be used as a component of available relative value as shown in operand designation of instruction/directive.

- Memory reference instruction (Load/store instruction, and bit manipulation instruction)
- Operation instruction (arithmetic operation instruction, saturated operation instruction, logical operation instruction)
- Branch instruction
- Area reservation directive

In assembler, the meaning of a label reference varies with the reference method and the differences used in the instructions/directives Details are shown below.

Table 4-20. Label Reference

Reference Method	Instructions Used	Meaning
#label	Memory reference instruction, operation instruction and jmp instruction	The absolute address of the position at which the definition of label (label) exists (Offset from address 0[Note 1]). This has a 32-bit address and must be expanded into two instructions except ld23, st23 or mov instruction.
	Area reservation directive	The absolute address of the position at which the definition of label (label) exists (Offset from address 0[Note 1]). Note that the 32-bit address is a value masked in accordance with the size of the area secured.
!label	Memory reference instruction, operation instruction	The absolute address of the position at which the definition of label (label) exists (Offset from address 0 [Note 1]). This has a 16-bit address and cannot expand instructions if instructions with 16-bit displacement or immediate are specified. If any other instructions are specified, expansion into appropriate one instruction is possible. If the address defined by label (label) is not within a range expressible by 16 bits, an error will be occur at the time of link.
	Area reservation directive	The absolute address of the position at which the definition of label (label) exists (Offset from address 0 [Note 1]). Note that the 32-bit address is a value masked in accordance with the size of the area secured.

Reference Method	Instructions Used	Meaning
label	Memory reference instruction, operation instruction	The offset in the section of the position where definition of the label (label) exists (offset from the initial address of the section where the definition of label (label) exists[Note 2]). This has a 32-bit offset and must be expanded into two instructions except ld23, st23 or mov instruction.
	Branch instruction except jmp instruction	The PC offset at the position where definition of label (label) exists (offset from the initial address of the instruction using the reference of label (label)).
	Area reservation directive	The offset in the section of the position where definition of the label (label) exists (offset from the initial address of the section where the definition of label (label) exists[Note 2]). Note that the 32-bit offset is a value masked in accordance with the size of the area secured.
%label	Memory reference instruction, operation instruction	This has a 16-bit offset and cannot expand instructions if instructions with 16-bit displacement or immediate are specified. If any other instructions are specified, expansion into appropriate one instruction is possible. If the address defined by label (label) is not within a range expressible by 16 bits, an error will be occurred at the time of link.
	Area reservation directive	The ep offset at the position where definition of the label (label) exists (offset from the address showing the element pointer). Note that the 32-bit offset is a value masked in accordance with the size of the area secured.
$label	Memory reference instruction, operation instruction	The gp offset at the position where definition of the label (label) exists (offset from the address showing the global pointer).

Notes 1. The offset from address 0 in object module file after link.

2. The offset from the first address of the section (output section) in which the definition of label (label) exists is allocated in the linked object module file.

The meanings of label references for memory reference instructions, operation instructions, branch instructions, and area allocation pseudo-instruction are shown below.

Table 4-21. Memory Reference Instruction

Reference Method	Meaning
#label[reg]	The absolute address of label (label) is treated as a displacement. This has a 32-bit value and must be expanded into two instructions except ld23 or st23 instruction. By setting #label[r0], reference by an absolute address can be specified. Part of [reg] can be omitted. If omitted, the assembler assumes that [r0] has been specified.

Reference Method	Meaning
label[reg]	The offset in the section of label (label) is treated as a displacement. This has a 32-bit value and must be expanded into two instructions except ld23 or st23 instruction. By specifying a register indicating the first address of section as reg and thereby setting label[reg], general register relative reference can be specified.
$label[reg]	The gp offset of label (label) is treated as a displacement. This has either a 32-bit or 16-bit value, from the section defined by label (label), and pattern of instruction expansion changes accordingly Note. If an instruction with a 16-bit value is expanded and the offset calculated from the address defined by label (label) is not within a range that can be expressed in 16 bits, an error is output at the time of link. By setting $label [gp], relative reference of the gp register (called a gp offset reference) can be specified. Part of [reg] can be omitted. If omitted, the assembler assumes that [gp] has been specified.
!label[reg]	The absolute address of label (label) is treated as a displacement. This has a 16-bit value and instruction is not expanded. If the address defined by label (label) cannot be expressed in 16 bits, an error is output at the time of link. By setting !lable[r0], reference by an absolute address can be specified. Part of [reg] can be omitted. If omitted, the assembler assumes that [r0] has been specified. However, unlike #label[reg] reference, instruction expansion is not executed.
%label[reg]	The offset from the ep symbol in the position where definition of the label (label) exists is treated as a displacement. This either has a 16-bit value, or depending on the instruction a value lower than this, and if it is not a value that can be expressed within this range, an error is output at the time of link. Part of [reg] can be omitted. If omitted, the assembler assumes that [ep] has been specified.

Note See "(h) gp offset reference".

Table 4-22. Operation Instructions

Reference Method	Significance
#label	The absolute address of label (label) is treated as an immediate. This has a 32-bit value and must be expanded into two instructions.
label	The offset in the section of label (label) is treated as an immediate. This has a 32-bit value and must be expanded into two instructions.
$label	The gp offset of label (label) is treated as an immediate. This either has a 32-bit or 16-bit value, from the section defined by label (label), and pattern of instruction changes accordingly Note 1. If an instruction with a 16-bit value is expanded and the offset calculated from the address defined by label (label) is not within a range that can be expressed in 16 bits, an error is output at the time of link.

Reference Method	Significance
!label	The absolute address of label (label) is treated as an immediate. This has a 16-bit value. If operation instruction of an architecture for which a 16-bit value can be specify Note 2 as an immediate are specified, and instruction is not expanded. If the add, mov, and mulh instructions are specified, expansion into appropriate 1-instruction is possible. No other instructions can be specified. If the value is not within a range that can be expressed in 16 bits, an error is output at the time of link.
%label	The offset from the ep symbol in the position where definition of the label (label) exists is treated as an immediate. This has a 16-bit value. If operation instruction of an architecture for which a 16-bit value can be specify Note 2 as an immediate are specified, and instruction is not expanded. This reference method can be specified only for operation instructions of an architecture for which a 16-bit value can be specified as an immediate, and add, mov, and mulh instructions. If the add, mov, and mulh instructions are specified, expansion into appropriate 1-instruction is possible. No other instructions can be specified. If the value is not within a range that can be expressed in 16 bits, an error is output at the time of link.

Notes 1. See "(h) gp offset reference".

2. The instructions for which a 16-bit value can be specified as an immediate are the addi, andi, movea, mulhi, ori, satsubi, and xori instructions.

Table 4-23. Branch Instructions

Reference Method	Meaning
#label	In jmp instruction, the absolute address of label (label) is treated as a jump destination address. This has a 32-bit value and must be expanded into two instructions.
label	In branch instructions other than the jmp instruction, PC offset of the label (label) is treated as a displacement. This has a 22-bit value, and if it is not within a range that can be expressed in 22 bits, an error is output at the time of link.

Table 4-24. Area Reservation Directives

Reference Method	Meaning
#label !label	In .db4/.db2/.db directive, the absolute address of the label (label) is treated as a value. This has a 32-bit value, but is masked in accordance with the bit width of each directives
label	In .db4/.db2/.db directive, the offset in the section defined by label (label) is treated as a value. This has a 32-bit value, but is masked in accordance with the bit width of each directives
%label	The .db4, .db2, and .db directives treat the ep offset of label *label* as a value. This has a 32-bit value, but is masked in accordance with the bit width of each directives

Reference Method	Meaning
$label	The .db4, .db2, and .db directives treat the gp offset of label *label* as a value. This has a 32-bit value, but is masked in accordance with the bit width of each directives

(g) ep offset reference

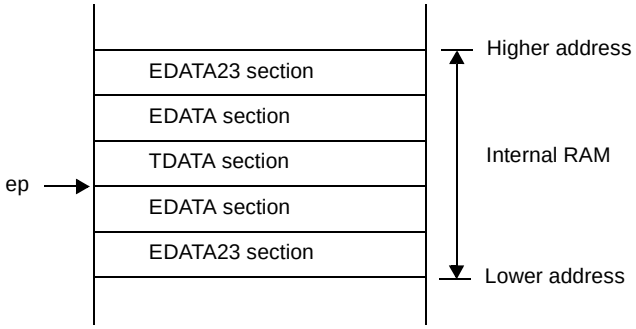
This section describes the ep offset reference. The CC-RH assumes that data explicitly stored in internal RAM is shown below.

Reference through the offset from address indicated by the element pointer (ep).

Data in the internal RAM is divided into the following two groups.

- TDATA/TDATA4/TBSS4/TDATA5/TBSS5/TDATA7/TBSS7/TDATA8/TBSS8 section (Data is referred by memory reference instructions (sld/sst) in a small code size)
- EDATA/EBSS section (Data is referred by memory reference instructions (ld/st) in a large code size)
- EDATA23/EBSS23 section (Data is referred by memory reference instructions (ld23/st23) in a large code size)

Figure 4-2. Memory Location Image of Internal RAM



<1> Data allocation

In internal RAM, data is allocated to the sections as follows:

- When developing a program in C
  Allocate data by specifying the "sdata", or "sdata23" section type in the "#pragma section" instruction.

- When developing a program in assembly language
  Data is allocated to the section of tdata, tdata4, tbss4, tdata5, tbss5, tdata7, tbss7, tdata8, tbss8, sdata, sbss, sdata23, or sbss23 relocation attribute sections by the section definition directives.

<2> Data reference

In cases where a reference via %label is made, the assembler generates a sequence of machine-language instructions to perform reference to the data at the corresponding ep offset.

Example

```
        .dseg   EDATA
sdata:  .db2    0xFFF0
        .dseg   DATA
data:   .db2    0xFFF0
        .cseg   TEXT
        ld.h    %sdata, r20     ; (1)
        ld.h    %data, r20      ; (2)
```

The assembler generates machine-language instructions that treat references via %label as ep-offset references in the cases of both (1) and (2).
The assembler assumes that the section in which the data is located is correct. As a result, it will not detect errors in data placement.

Example

```
        .dseg   DATA
label:
        .dhw    0x0001
        .cseg   TEXT
        ld.h    %label[ep], r20
```

Instructions are coded to allocate a label to the EDATA section and to perform reference by ep offset. However, label is allocated to the DATA section because of the allocation error. In this case, the assembler loads the data in the base register ep symbol value + offset value in the DATA section of label.

(h) gp offset reference

This section describes the gp offset reference. The CC-RH assumes that data stored in external RAM (other than .sedata/.sebss section explained on the previous page) is basically shown below.

Referred by the offset from the address indicated by global pointer (gp).

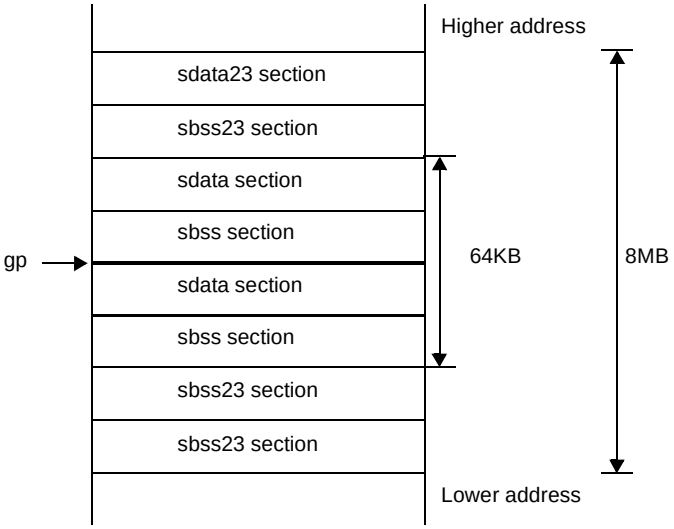
If r0-relative memory allocation for internal ROM or RAM is not done with the "#pragma section" command of C, or an assembly language section definition directive, all data is subject to gp offset reference.

<1> Data allocation

The memory reference instruction (ld/st) of the machine instruction of the RH850 family can accept 16-bit immediate or 23-bit immediate as a displacement. For this reason, the CC-RH classifies data into the following three types. Data of the first type is allocated to the sdata or sbss section, the second type is allocated to the sdata23 or sbss23 section, the 3rd type is allocated to the data or bss section.

- Data allocated to a memory range that can be referred by using the global pointer (gp) and a 16-bit displacement.
- Data allocated to a memory range that can be referred by using the global pointer (gp) and a 23-bit displacement.
- Data allocated to a memory range that can be referred by using the global pointer (gp) and (constructed by many instructions) a 32-bit displacement.

Figure 4-3. Memory Location Image for gp Offset Reference Section



Remark The sum of sdata- and sbss-attribute sections is 64 KB. gp is the center of the sdata section and sbss section.

Data in the sdata/sbss/sdata23/sbss23 sections can be referred by using a single instruction. To reference data in the data/bss sections, however, two or more instructions are necessary. Therefore, the more data allocated to the sdata/sbss/sdata23/sbss23 sections, the higher the execution efficiency and object efficiency of the generated machine instructions. However, the size of the memory range that can be referred with a 16-bit and 23-bit displacement is limited.
If all the data cannot be allocated to the sdata/sbss/sdata23/sbss23 sections, it becomes necessary to determine which data is to be allocated to the sdata/sbss/sdata23/sbss23 sections.
The CC-RH "allocates as much data as possible to the sdata/sbss/sdata23/sbss23 sections". By default, all data items are allocated to the sdata/sbss/sdata23/sbss23 sections. The data to be allocated can be selected as follows:

- When using a program to specify the section to which data will be allocated.
  Explicitly allocate data that will be frequently referred to the sdata/sbss/sdata23/sbss23 sections. For allocation, use a section definition directive when using the assembly language, or the #pragma section command when using C.

<2> Data reference

Using the data allocation method explained above, the assembler generates a machine instruction string that performs:

- Reference by using a 16-bit displacement for gp offset reference to data allocated to the sdata- and sbss- attribute sections.
- Reference by using a 32-bit displacement (consisting of two or more machine instructions) for gp offset reference to data allocated to the data- and bss-attribute sections.

Example

```
        .dseg   DATA
data:   .db4    0xFFF00010      ; (1)
        .cseg   TEXT
        ld.w    $data[gp], r20  ; (2)
```

The assembler generates a machine instruction string, equivalent to the following instruction string for the ld.w instruction in (2), that performs gp offset reference of the data defined in (1).Note

```
movhi   HIGHW1($data), gp, r1
ld.w    LOWW($data)[r1], r20
```

Note See "(i) About HIGH/LOW/HIGHW/LOWW/HIGHW1", for details of HIGHW1/LOWW.

The assembler processes files on a one-by-one basis. Consequently, it can identify to which attribute section data having a definition in a specified file has been allocated, but cannot identify the section to which data not having a definition in a specified file has been allocated.
To develop a program in an assembly language, therefore, specify the size of the data (actually, a label for which there is no definition in a specified file and which is referred by a gp offset) for which there is no definition in a specified file, by using the .extern directives.

```
.extern data, 4         ; (1)
.cseg   TEXT
ld.w    $data[gp], r20  ; (2)
```

To develop a program in C, the C compiler of the CC-RH automatically generates the .extern directive, thus output the code which specifies the size of data not having a definition in the specified file (actually, a label for which there is no definition in a specified file and which is referred by a gp offset).

Remark The handling of gp offset reference (specifically, memory reference instructions that use a relative expression having the gp offset of a label as their displacement) by the assembler is summarized below.

- If the data has a definition in a specified file.
  - If the data is to be allocated to the sdata or sbss sectionNote.
    Generates a machine instruction that performs reference by using a16-bit displacement.
  - If the data is not allocated to the sdata or sbss section.
    Generates a machine instruction string that performs reference by using a 32-bit displacement.

Note If the value of the constant expression of a relative expression in the form of "label + constant expression" exceeds 16 bits, the assembler generates a machine instruction string that performs reference using a 32-bit displacement.

- If the data does not have a definition in a specified file.
  Assumes that the data is to be allocated to the sdata or sbss section (the label referenced by gp offset has a definition in the sdata/sbss section) and generates a machine instruction that performs reference by using a 16-bit displacement.

(i) About HIGH/LOW/HIGHW/LOWW/HIGHW1

<1> To store 32-bit constant value in a register

To store a 32-bit constant value in a register, the assembler performs instruction expansion, and generates an instruction string, by using the movhi and movea instructions. These divide the 32-bit constant value into the higher 16 bits and lower 16 bits.

Example

`mov 0x18000, r11`	`movhi HIGHW1(0x18000), r0, r1` `movea LOWW(0x18000), r1, r11`

At this time, the movea instruction, used to store the lower 16 bits in the register, sign-extends the specified 16-bit value to a 32-bit value. To adjust the sign-extended bits, the assembler does not merely store the higher 16 bits in a register when using the movhi instruction, instead it stores the following value in the register.

Higher 16 bits + the most significant bit (bit of bit number 15) of the lower 16 bits

<2> To refer memory by using 32-bit displacement

The assembler performs instruction expansion to refer the memory by using a 32-bit displacement, and generates an instruction string that performs the reference, by using the movhi and memory reference instructions and thereby constituting a 32-bit displacement from the higher 16 bits and lower 16 bits of the 32-bit displacement.

Example

`ld.w 0x18000[r11], r12`	`movhi HIGHW1(0x18000), r11, r1` `ld.w LOWW(0x18000)[r1], r12`

At this time, the memory reference instruction of machine instructions that uses the lower 16 bits as a displacement sign-extends the specified 16-bit displacement to a 32-bit value. To adjust the sign-extended bits, the assembler does not merely configure the displacement of the higher 16 bits by using the movhi instruction, instead it configures the following displacement.

Higher 16 bits + the most significant bit (bit of bit number 15) of the lower 16 bits

<3> HIGHW/LOWW/HIGHW1/HIGH/LOW

In the next table, the assembler can specify the higher 16 bits of a 32-bit value, the lower 16 bits of a 32-bit value, the value of the higher 16 bits + bit 15 of a 32-bit value, the higher 8 bits of a 16-bit value, and the lower 8 bits of a 16-bit value by using HIGHW, LOWW, HIGHW, HIGH, and LOW.[Note]

Note If this information cannot be internally resolved by the assembler, it is reflected in the relocation information and subsequently resolved by the link editor.

Table 4-25. Area Reservation Directives

HIGHW/LOWW/HIGHW1/ HIGH/LOW	Meaning
HIGHW (*value*)	Higher 16 bits of *value*
LOWW (*value*)	Lower 16 bits of *value*
HIGHW1 (*value*)	Higher 16 bits of *value* + bit value of bit number 15 of *value*
HIGH (*value*)	Upper 8 bits of the lower 16 bits of *value*
LOW (*value*)	Lower 8 bits of *value*

Example

```
        .dseg   DATA
L1:
            :
        .cseg   TEXT
        movhi   HIGHW ($L1), r0, r10  ; Stores the higher 16 bits of the gp
                                      ; offset value of L1 in the higher 16
                                      ; bits of r10, and the lower 16 bits to 0
        movea   LOWW ($L1), r0, r10   ; Sign-extends the lower 16 bits of the gp
                                      ; offset of L1 and stores to r10
            :
        movhi   HIGHW1 ($L1), r0, r1  ; Stores the gp offset value of L1 in r10
        movea   LOWW ($L1), r1, r10
```

4.8 Description of Instructions

This section describes the instructions of the assembly language supported by the assembler.
For details of the machine instructions generated by the assembler, see the "Each Device User Manual".

Instruction

Indicates the meaning of instruction.

[Syntax]

Indicates the syntax of instruction.

[Function]

Indicates the function of instruction.

[Description]

Indicates the operating method of instruction.

[Flag]

Indicates the operation of flag (PSW) by the execution of instruction.
However, in (set1, clr1, not1) bit operation instruction, indicates the flag value before execution.
"---" of table indicates that the flag value is not changed.

[Caution]

Indicates the caution in instruction.

4.8.1 Load/Store instructions

This section describes the load/store instructions. Next table lists the instructions described in this section.
See the RH850 product user's manual and architecture edition for details.

Table 4-26. Load/Store Instructions

Instruction		Meaning
ld	ld.b	Byte data load
	ld.h	Halfword data load
	ld.w	Word data load
	ld.bu	Unsigned byte data load
	ld.hu	Unsigned halfword data load
sld	sld.b	Byte data load (short format)
	sld.h	Halfword data load (short format)
	sld.w	Word data load (short format)
	sld.bu	Unsigned byte data load (short format)
	sld.hu	Unsigned halfword data load (short format)
ld23	ld23.b	Byte data load
	ld23.h	Halfword data load
	ld23.w	Word data load
	ld23.bu	Unsigned byte data load
	ld23.hu	Unsigned halfword data load
	ld23.dw	Doubleword data load
st	st.b	Byte data store
	st.h	Halfword data store
	st.w	Word data store
sst	sst.b	Byte data store (short format)
	sst.h	Halfword data store (short format)
	sst.w	Word data store (short format)
st23	st23.b	Byte data store
	st23.h	Halfword data store
	st23.w	Word data store
	st23.dw	Doubleword data store

ld

Data is loaded.

[Syntax]

- ld.b disp[reg1], reg2
- ld.h disp[reg1], reg2
- ld.w disp[reg1], reg2
- ld.bu disp[reg1], reg2
- ld.hu disp[reg1], reg2

The following can be specified for displacement (disp):

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with LOWW applied

[Function]

The ld.b, ld.bu, ld.h, ld.hu, and ld.w instructions load data of 1 byte, 1 halfword, and 1 word, from the address specified by the first operand, int the register specified by the second operand.

[Description]

- If any of the following is specified for disp, the assembler generates one ld machine instruction[Note]. In the following explanations, ld denotes the ld.b/ld.h/ld.w/ld.bu/ld.hu instructions.

(a) Absolute expression having a value in the range of -32,768 to +32,767

`ld disp16[reg1], reg2`	`ld disp16[reg1], reg2`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`ld $label[reg1], reg2`	`ld $label[reg1], reg2`

(c) Absolute expression having !label or %label

`ld !label[reg1], reg2`	`ld !label[reg1], reg2`
`ld %label[reg1], reg2`	`ld %label[reg1], reg2`

(d) Expression with , LOWW

`ld disp16[reg1], reg2`	`ld disp16[reg1], reg2`

Note The ld machine instruction takes an immediate value in the range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF) as the displacement

- If any of the following is specified for disp, the assembler performs instruction expansion to generate multiple machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

`ld disp[reg1], reg2`	`movhi HIGHW1(disp), reg1, r1` `ld LOWW(disp)[r1], reg2`

(b) Relative expression having #label or label, or that having $label for a label having definition in the sdata/sbss-attribute section

`ld #label[reg1], reg2`	`movhi HIGHW1(#label), reg1, r1` `ld LOWW(#label)[r1], reg2`
`ld label[reg1], reg2`	`movhi HIGHW1(label), reg1, r1` `ld LOWW(label)[r1], reg2`
`ld $label[reg1], reg2`	`movhi HIGHW1($label), reg1, r1` `ld LOWW($label)[r1], reg2`

- If disp is omitted, the assembler assumes 0.
- If a relative expression having #label, or a relative expression having #label and with LOWW applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [r0] is specified.
- If a relative expression having $label, or a relative expression having $label and with LOWW applied, is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [gp] is specified.
- Specify an ld23 instruction to specify an ld instruction with a 23 bit-wide disp..

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- ld.b and ld.h sign-extend the data of 1 byte and 1 halfword, respectively, and load the data into a register as 1 word.
- If a value that is not a multiple of 2 is specified as disp of ld.h, ld.w, or ld.hu, the assembler and link editor aligns disp with 2 and generates a code. Then, the assembler and link editor outputs either one of the following messages.

W0550010 : Illegal displacement in ld instruction.
E0562332 : Relocation value is odd number : "*file*"-"*section*"-"*offset*"

- If r0 is specified as the second operand of ld.bu and ld.hu, the assembler outputs the following message and stops assembling.

E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

sld

Data is loaded (short format).

[Syntax]

- sld.b disp7[ep], reg2
- sld.h disp8[ep], reg2
- sld.w disp8[ep], reg2
- sld.bu disp4[ep], reg2
- sld.hu disp5[ep], reg2

The following can be specified for displacement (disp4/5/7/8):

- Absolute expression having a value of up to 7 bits for sld.b, 8 bits for sld.h and sld.w, 4 bits for sld.bu, and 5 bits for sld.hu.
- Relative expression

[Function]

The sld.b, sld.bu, sld.h, sld.hu, and sld.w instructions load the data of 1 byte, 1 halfword, and 1 word, from the address obtained by adding the displacement specified by the first operand to the contents of register ep, to the register specified by the second operand.

[Description]

The assembler generates one sld machine instruction. Base register specification "[ep]" can be omitted.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- sld.b and sld.h sign-extend and store data of 1 byte and 1 halfword, respectively, in the register as 1 word.
- If a value that is not a multiple of 2 is specified as disp8 of sld.h or disp5 of sld.hu, and if a value that is not a multiple of 4 is specified as disp8 of sld.w, the assembler aligns disp8 or disp5 with multiples of 2 and 4, respectively, and generates a code. Then, the assembler and link editor outputs either one of the following messages.

W0550010 : Illegal displacement in ld instruction.
E0562332 : Relocation value is odd number : "*file*"-"*section*"-"*offset*"

- If a value exceeding 127 is specified for disp7 of sld.b, a value exceeding 255 is specified for disp8 of sld.h and sld.w, a value exceeding 16 is specified for disp4 of sld.bu, and a value exceeding 32 is specified for disp5 of sld.hu, the assembler outputs the following message, and generates code in which disp7, disp8, disp4, and disp5 are masked with 0x7F, 0xFF, 0xF, and 0x1F, respectively.

```
W0550011 : Illegal operand (range error in immediate).
```

- If r0 is specified as the second operand of the sld.bu and sld.hu, the assembler outputs the following message and stops assembling.

```
E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).
```

ld23

Data is loaded.

[Syntax]

- ld23.b disp23[reg1], reg2
- ld23.h disp23[reg1], reg2
- ld23.w disp23[reg1], reg2
- ld23.bu disp23[reg1], reg2
- ld23.hu disp23[reg1], reg2
- ld23.dw disp23[reg1], reg2

The following can be specified for displacement (disp):

- Absolute expression having a value of up to 23 bits
- Relative expression

[Function]

The ld23.b, ld23.bu, ld23.h, ld23.hu, and ld23.w instructions load data of 1 byte, 1 halfword, and 1 word, from the address specified by the first operand, int the register specified by the second operand. The ld23.dw instruction loads a double word of data from the address specified in the first operand, then register reg2 specified in the second operand into the lower 32 bits, and reg2 + 1 into the upper 32 bits.

[Description]

- The assembler generates a 48-bit ld[Note] instruction in machine language.

Note The ld machine instruction takes an immediate value in the range of -4,194,304 to +4,194,303 (0xFFC00000 to 0x3FFFFF) as the displacement

- If disp23 is omitted, the assembler assumes 0.
- If a relative expression having #labelis specified as disp23, [reg1] can be omitted. If omitted, the assembler assumes that [r0] is specified.
- If a relative expression having $label is specified as disp23, [reg1] can be omitted. If omitted, the assembler assumes that [gp] is specified.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- ld23.b and ld23.h sign-extend the data of 1 byte and 1 halfword, respectively, and load the data into a register as 1 word.
- If a value that is not a multiple of 2 is specified as disp of ld23.h, ld23.w, ld23.hu, or ld23.dw, the assembler and link editor aligns disp with 2 and generates a code. Then, the assembler and link editor outputs either one of the following messages.

W0550010 : Illegal displacement in ld instruction.
E0562332 : Relocation value is odd number : "*file*"-"*section*"-"*offset*"

- If r0 is specified as the second operand of ld.bu and ld.hu, the assembler outputs the following message and stops assembling.

E0550240 : Illegal operand (cannot use r0 as destination in V850E mode).

- A message is output if an odd-numbered register is specified in the second operand of the ld23.dw instruction.

W0550013 : *register* used as *kind* register.

st

Data is stored.

[Syntax]

- st.b reg2, disp[reg1]
- st.h reg2, disp[reg1]
- st.w reg2, disp[reg1]

The following can be specified as a displacement (disp):

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with LOWW applied

[Function]

The st.b, st.h, and st.w instructions store the data of the lower 1 byte, lower 1 halfword, and 1 word, respectively, of the register specified by the first operand to the address specified by the second operand.

[Description]

- If any of the following is specified as disp, the assembler generates one st machine instruction[Note]. In the following explanations, st denotes the st.b/st.h/st.w instructions.

(a) Absolute expression having a value in the range of -32,768 to +32,767

`st reg2, disp16[reg1]`	`st disp16[reg1], reg2`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`st reg2, $label[reg1]`	`st $label[reg1], reg2`

(c) Absolute expression having !label or %label

`st reg2, !label[reg1]`	`st !label[reg1], reg2`
`st reg2, %label[reg1]`	`st %label[reg1], reg2`

(d) Expression withLOWW

`st reg2, disp16[reg1]`	`st disp16[reg1], reg2`

Note The st machine instruction takes an immediate value in the range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF) as the displacement.

- If any of the following is specified as disp, the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

`st reg2, disp[reg1]`	`movhi HIGHW1(disp), reg1, r1` `st LOWW(disp)[r1], reg2`

(b) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`st reg2, #label[reg1]`	`movhi HIGHW1(#label), reg1, r1` `st LOWW(#label)[r1], reg2`
`st reg2, label[reg1]`	`movhi HIGHW1(label), reg1, r1` `st LOWW(label)[r1], reg2`
`st reg2, $label[reg1]`	`movhi HIGHW1($label), reg1, r1` `st LOWW($label)[r1], reg2`

- If disp is omitted, the assembler assumes 0.
- If a relative expression with #label, or a relative expression with #label and with LOWW applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [r0] is specified.
- If a relative expression with $label, or a relative expression with $label and with LOWW applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [gp] is specified.
- Specify an st23 instruction to specify an st instruction with a 23 bit-wide disp.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If a value that is not a multiple of 2 is specified as the disp of st.h or st.w, the assembler aligns disp with 2 and generates a code. Then, the assembler outputs either one of the following messages.

W0550010 : Illegal displacement in ld instruction.
E0562332 : Relocation value is odd number : "*file*"-"*section*"-"*offset*"

sst

Data is stored (short format).

[Syntax]

- sst.b reg2, disp7[ep]
- sst.h reg2, disp8[ep]
- sst.w reg2, disp8[ep]

The following can be specified for displacement (disp7/8):

- Absolute expression having a value of up to 7 bits for sst.b or 8 bits for sst.h and sst.w
- Relative expression

[Function]

The sst.b, sst.h, and sst.w instructions store the data of the lower 1 byte, lower 1 halfword, and 1 word, respectively, of the register specified by the first operand to the address obtained by adding the displacement specified by the second operand to the contents of register ep.

[Description]

The assembler generates one sst machine instruction. Base register specification "[ep]" can be omitted.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If a value that is not a multiple of 2 is specified as disp8 of sst.h, and if a value that is not a multiple of 4 is specified as disp8 of sst.w, the assembler aligns disp8 with multiples of 2 and 4, respectively, and generates a code. Then, the assembler outputs either one of the following messages.

W0550010 : Illegal displacement in ld instruction.
E0562332 : Relocation value is odd number : "*file*"-"*section*"-"*offset*"

- If a value exceeding 127 is specified as disp7 of sst.b, and if a value exceeding 255 is specified as disp8 of sst.h and sst.w, the assembler outputs the following message, and generates codes disp7 and disp8, masked with 0x7F and 0xFF, respectively.

W0550011 : Illegal operand (range error in immediate).

st23

Data is stored.

[Syntax]

- st23.b reg2, disp23[reg1]
- st23.h reg2, disp23[reg1]
- st23.w reg2, disp23[reg1]
- st23.dw reg2, disp23[reg1]

The following can be specified as a displacement (disp):
- Absolute expression having a value of up to 23 bits
- Relative expression

[Function]

The st23.b, st23.h, and st23.w instructions store the data of the lower 1 byte, lower 1 halfword, and 1 word, respectively, of the register specified by the first operand to the address specified by the second operand. The st23.dw instruction loads the word data from the register specified in the first operand into the lower 32 bits, and the word data at reg2 + 1 into the upper 32 bits, and then stores this double-word data into the address specified in the second operand.

[Description]

- The assembler generates one st machine instruction[Note].

Note The st machine instruction takes an immediate value in the range of -4,194,304 to +4,194,303 (0xFFC00000 to 0x3FFFFF) as the displacement.

- If disp23 is omitted, the assembler assumes 0.
- If a relative expression with #label is specified as disp23, [reg1] can be omitted. If omitted, the assembler assumes that [r0] is specified.
- If a relative expression with $label is specified as disp23, [reg1] can be omitted. If omitted, the assembler assumes that [gp] is specified.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If a value that is not a multiple of 2 is specified as the disp of st.h or st.w, the assembler aligns disp with 2 and generates a code. Then, the assembler outputs either one of the following messages.

W0550010 : Illegal displacement in ld instruction.
E0562332 : Relocation value is odd number : "*file*"-"*section*"-"*offset*"

- A message is output if an odd-numbered register is specified in the first operand of the st23.dw instruction.

W0550013 : *register* used as *kind* register.

4.8.2 Arithmetic operation instructions

This section describes the arithmetic operation instructions. Next table lists the instructions described in this section. See the RH850 product user's manual and architecture edition for details.

Table 4-27. Arithmetic Operation Instructions

Instruction	Meaning
add	Adds
addi	Adds (immediate)
adf	Adds with condition
sub	Subtracts
subr	Subtracts reverse
sbf	Subtracts with condition
mulh	Multiplies signed data (halfword)
mulhi	Multiplies signed data (halfword immediate)
mul	Multiplies signed data (word)
mulu	Multiplies unsigned data
mac	Multiplies and adds signed word data
macu	Multiplies and adds unsigned word data
divh	Divides signed data (halfword)
div	Divides signed data (word)
divhu	Divides unsigned data (halfword)
divu	Divides unsigned data (word)
divq	Division of (signed) word data (variable steps)
divqu	Division of (unsigned) word data (variable steps)
cmp	Compares
mov	Moves data
movea	Moves execution address
movhi	Moves higher half-word
mov32	Moves 32-bit data
cmov	Moves data depending on the flag condition
setf	Sets flag condition
sasf	Sets the flag condition after a logical left shift
bins	Insert bit in register
rotl	Rotate

See the device with an instruction set of RH850 product user's manual and architecture edition for details about the device with an instruction set of RH850.

add

Adds.

[Syntax]

- add reg1, reg2
- add imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "add reg1, reg2"
  Adds the value of the register specified by the first operand to the value of the register specified by the second operand, and stores the result into the register specified by the second operand.
- Syntax "add imm, reg2"
  Adds the value of the absolute expression or relative expression specified by the first operand to the value of the register specified by the second operand, and stores the result in the register specified by the second operand.

[Description]

- If this instruction is executed in syntax "add reg1, reg2", the assembler generates one add machine instruction.
- If the following is specified as imm in syntax "add imm, reg2", the assembler generates one add machine instruction[Note].

(a) Absolute expression having a value in the range of -16 to +15

`add imm5, reg`	`add imm5, reg`

Note The add machine instruction takes a register or immediate value in the range of -16 to +15 (0xFFFFFFF0 to 0xF) as the first operand.

- If the following is specified for imm in syntax "add imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`add imm16, reg`	`addi imm16, reg, reg`

(b) Absolute expression having a value exceeding the range of -32,768 to +32,767
If all the lower 16 bits of the value of imm are 0

`add imm, reg`	`movhi HIGHW(imm), r0, r1` `add r1, reg`

Else

`add imm, reg`	`mov imm, r1` `add r1, reg`

(c) Relative expression having !label or %label, or that having $label for a label with a definition in the sdata/sbss-attribute section

`add !label, reg`	`addi !label, reg, reg`
`add %label, reg`	`addi %label, reg, reg`
`add $label, reg`	`addi $label, reg, reg`

(d) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`add #label, reg`	`mov #label, r1` `add r1, reg`
`add label, reg`	`mov label, r1` `add r1, reg`
`add $label, reg`	`mov $label, r1` `add r1, reg`

[Flag]

CY	1 if a carry occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

addi

Adds immediate.

[Syntax]

- addi imm, reg1, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

[Function]

Adds the value of the absolute expression, relative expression, or expression with HIGHW, LOWW, or HIGHW1 applied, specified by the first operand, to the value of the register specified by the second operand, and stores the result into the register specified by the third operand.

[Description]

- If the following is specified for imm, the assembler generates one addi machine instruction[Note].

(a) Absolute expression having a value in the range of -32,768 to +32,767

`addi imm16, reg1, reg2`	`addi imm16, reg1, reg2`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`addi $label, reg1, reg2`	`addi $label, reg1, reg2`

(c) Relative expression having !label or %label

`addi !label, reg1, reg2`	`addi !label, reg1, reg2`
`addi %label, reg1, reg2`	`addi %label, reg1, reg2`

(d) Expression with HIGHW, LOWW, or HIGHW1

`addi imm16, reg1, reg2`	`addi imm16, reg1, reg2`

Note The addi machine instruction takes an immediate value in the range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF)as the first operand.

- If the following is specified for imm, the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

<1> If all the lower 16 bits of the value of imm are 0

If reg2 is r0

`addi imm, reg1, r0`	`movhi HIGHW(imm), r0, r1` `add reg1, r1`

Else

`addi imm, reg1, reg2`	`movhi HIGHW(imm), r0, reg2` `add reg1, reg2`

<2> Else

If reg2 is r0

`addi imm, reg1, r0`	`mov imm, r1` `add reg1, r1`

Else

`addi imm, reg1, reg2`	`mov imm, reg2` `add reg1, reg2`

(b) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

If reg2 is r0

`addi #label, reg1, r0`	`mov #label, r1` `add reg1, r1`
`addi label, reg1, r0`	`mov label, r1` `add reg1, r1`
`addi $label, reg1, r0`	`mov $label, r1` `add reg1, r1`

Else

`addi #label, reg1, reg2`	`mov #label, reg2` `add reg1, reg2`
`addi label, reg1, reg2`	`mov label, reg2` `add reg1, reg2`
`addi $label, reg1, reg2`	`mov $label, reg2` `add reg1, reg2`

[Flag]

CY	1 if a carry occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

adf

Adds on condition flag.

[Syntax]

- adf imm4, reg1, reg2, reg3
- adf*cnd* reg1, reg2, reg3

The following can be specified for imm4:

- Absolute expression having a value up to 4 bits (0xD cannot be specified)

[Function]

- Syntax "adf imm4, reg1, reg2, reg3"
  It compares the current flag condition with the flag condition indicated by the value of the lower 4 bits of the absolute expression (see "Table 4-28. adfcnd Instruction List") specified by the first operand.
  If the values match, adds the word data of the register specified by the second operand to the word data of the register specified by the third operand. And 1 is added to the addition result and that result is stored in the register specified by the fourth operand.
  If the values not match, adds the word data of the register specified by the second operand to the word data of the register specified by the third operand. And that result is stored in the register specified by the fourth operand.
- Syntax "adf*cnd* reg1, reg2, reg3"
  It compares the current flag condition with the flag condition indicated by the string in the *cnd*"part.
  If the values match, adds the word data of the register specified by the first operand to the word data of the register specified by the second operand. And 1 is added to the addition result and that result is stored in the register specified by the third operand.
  If the values not match, adds the word data of the register specified by the first operand to the word data of the register specified by the second operand. And that result is stored in the register specified by the third operand.

[Description]

- For the adf instruction, the assembler generates one adf machine instruction.
- For the adf*cnd* instruction, the assembler generates the corresponding adf instruction (see "Table 4-28. adfcnd Instruction List") and expands it to syntax "adf imm4, reg1, reg2, reg3".

Table 4-28. adf*cnd* Instruction List

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
adfgt	((S xor OV) or Z) = 0	Greater than (signed)	adf 0xF
adfge	(S xor OV) = 0	Greater than or equal (signed)	adf 0xE
adflt	(S xor OV) = 1	Less than (signed)	adf 0x6
adfle	((S xor OV) or Z) = 1	Less than or equal (signed)	adf 0x7
adfh	(CY or Z) = 0	Higher (Greater than)	adf 0xB
adfnl	CY = 0	Not lower (Greater than or equal)	adf 0x9
adfl	CY = 1	Lower (Less than)	adf 0x1
adfnh	(CY or Z) = 1	Not higher (Less than or equal)	adf 0x3
adfe	Z = 1	Equal	adf 0x2
adfne	Z = 0	Not equal	adf 0xA

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
adfv	OV = 1	Overflow	adf 0x0
adfnv	OV = 0	No overflow	adf 0x8
adfn	S = 1	Negative	adf 0x4
adfp	S = 0	Positive	adf 0xC
adfc	CY = 1	Carry	adf 0x1
adfnc	CY = 0	No carry	adf 0x9
adfz	Z = 1	Zero	adf 0x2
adfnz	Z = 0	Not zero	adf 0xA
adft	always 1	Always 1	adf 0x5

[Flag]

CY	1 if there is carry from MSB (Most Significant Bit), 0 if not
OV	1 if overflow occurred, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

[Caution]

- If an absolute expression having a value exceeding 4 bits is specified as imm4 of the adf instruction, the following message is output, and assembly continues using the lower 4 bits of the specified value.

```
W0550011 : illegal operand (range error in immediate).
```

- If 0xD is specified as imm4 of the adf instruction, the following message is output, and assembly is stopped.

```
E0550261 : illegal condition code.
```

sub

Subtracts.

[Syntax]

- sub reg1, reg2
- sub imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "sub reg1, reg2"
  Subtracts the value of the register specified by the first operand from the value of the register specified by the second operand, and stores the result in the register specified by the second operand.
- Syntax "sub imm, reg2"
  Subtracts the value of the absolute expression or relative expression specified by the first operand from the value of the register specified by the second operand, and stores the result into the register specified by the second operand.

[Description]

- If the instruction is executed in syntax "sub reg1, reg2", the assembler generates one sub machine instruction.
- If the instruction is executed in syntax "sub imm, reg2", the assembler executes instruction expansion and generates one or more machine instructions[Note].

(a) 0

`sub 0, reg`	`sub r0, reg`

(b) Absolute expression having a value of other than 0 within the range of -16 to +15

`sub imm5, reg`	`mov imm5, r1` `sub r1, reg`

(c) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`sub imm16, reg`	`movea imm16, r0, r1` `sub r1, reg`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`sub imm, reg`	`movhi HIGHW(imm), r0, r1` `sub r1, reg`

Else

`sub imm, reg`	`mov imm, r1` `sub r1, reg`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`sub $label, reg`	`movea $label, r0, r1` `sub r1, reg`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`sub #label, reg`	`mov #label, r1` `sub r1, reg`
`sub label, reg`	`mov label, r1` `sub r1, reg`
`sub $label, reg`	`mov $label, r1` `sub r1, reg`

Note The sub machine instruction does not take an immediate value as an operand.

[Flag]

CY	1 if a borrow occurs from MSB (Most Significant Bit),0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

subr

Subtracts reverse.

[Syntax]

- subr reg1, reg2
- subr imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "subr reg1, reg2"
  Subtracts the value of the register specified by the first operand from the value of the register specified by the second operand, and stores the result in the register specified by the second operand.
- Syntax "subr imm, reg2"
  Subtracts the value of the absolute expression or relative expression specified by the first operand from the value of the register specified by the second operand, and stores the result into the register specified by the second operand.

[Description]

- If the instruction is executed in syntax "subr reg1, reg2", the assembler generates one subr machine instruction.
- If the instruction is executed in syntax "subr imm, reg2", the assembler executes instruction expansion and generates one or more machine instructions[Note].

(a) 0

`subr 0, reg`	`subr r0, reg`

(b) Absolute expression having a value of other than 0 within the range of -16 to +15

`subr imm5, reg`	`mov imm5, r1` `subr r1, reg`

(c) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`subr imm16, reg`	`movea imm16, r0, r1` `subr r1, reg`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`subr imm, reg`	`movhi HIGHW(imm), r0, r1` `subr r1, reg`

Else

`subr imm, reg`	`mov imm, r1` `subr r1, reg`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`subr $label, reg`	`movea $label, r0, r1` `subr r1, reg`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`subr #label, reg`	`mov #label, r1` `subr r1, reg`
`subr label, reg`	`mov label, r1` `subr r1, reg`
`subr $label, reg`	`mov $label, r1` `subr r1, reg`

Note The subr machine instruction does not take an immediate value as an operand.

[Flag]

CY	1 if a borrow occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	1 if a borrow occurs from MSB (Most Significant Bit),0 if not

sbf

Subtracts on condition flag.

[Syntax]

- sbf imm4, reg1, reg2, reg3
- sbf*cnd* reg1, reg2, reg3

The following can be specified for imm4:

- Absolute expression having a value up to 4 bits (0xD cannot be specified)

[Function]

- Syntax "sbf imm4, reg1, reg2, reg3"
  It compares the current flag condition with the flag condition indicated by the value of the lower 4 bits of the absolute expression (see "Table 4-29. sbfcnd Instruction List") specified by the first operand.
  If the values match, subtracts the word data of the register specified by the second operand from the word data of the register specified by the third operand. And 1 is subtracted from the subtraction result and that result is stored in the register specified by the fourth operand.
  If the values not match, subtracts the word data of the register specified by the second operand from the word data of the register specified by the third operand. And that result is stored in the register specified by the fourth operand.
- Syntax "sbf*cnd* reg1, reg2, reg3"
  It compares the current flag condition with the flag condition indicated by the string in the "*cnd*" part.
  If the values match, subtracts the word data of the register specified by the first operand from the word data of the register specified by the second operand. And 1 is subtracted from the subtraction result and that result is stored in the register specified by the third operand.
  If the values not match, subtracts the word data of the register specified by the first operand from the word data of the register specified by the second operand. And that result is stored in the register specified by the third operand.

[Description]

- For the sbf instruction, the assembler generates one sbf machine instruction.
- For the adcond instruction, the assembler generates the corresponding sbf instruction (see "Table 4-29. sbfcnd Instruction List") and expands it to syntax "sbf imm4, reg1, reg2, reg3".

Table 4-29. sbf*cnd* Instruction List

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
sbfgt	((S xor OV) or Z) = 0	Greater than (signed)	sbf 0xF
sbfge	(S xor OV) = 0	Greater than or equal (signed)	sbf 0xE
sbflt	(S xor OV) = 1	Less than (signed)	sbf 0x6
sbfle	((S xor OV) or Z) = 1	Less than or equal (signed)	sbf 0x7
sbfh	(CY or Z) = 0	Higher (Greater than)	sbf 0xB
sbfnl	CY = 0	Not lower (Greater than or equal)	sbf 0x9
sbfl	CY = 1	Lower (Less than)	sbf 0x1
sbfnh	(CY or Z) = 1	Not higher (Less than or equal)	sbf 0x3

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
sbfe	Z = 1	Equal	sbf 0x2
sbfne	Z = 0	Not equal	sbf 0xA
sbfv	OV = 1	Overflow	sbf 0x0
sbfnv	OV = 0	No overflow	sbf 0x8
sbfn	S = 1	Negative	sbf 0x4
sbfp	S = 0	Positive	sbf 0xC
sbfc	CY = 1	Carry	sbf 0x1
sbfnc	CY = 0	No carry	sbf 0x9
sbfz	Z = 1	Zero	sbf 0x2
sbfnz	Z = 0	Not zero	sbf 0xA
sbft	always 1	Always 1	sbf 0x5

[Flag]

CY	1 if a borrow occurs from MSB (Most Significant Bit), 0 if not
OV	1 if overflow occurred, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

[Caution]

- If an absolute expression having a value exceeding 4 bits is specified as imm4 of the sbf instruction, the following message is output, and assembly continues using the lower 4 bits of the specified value.

```
W0550011 : illegal operand (range error in immediate).
```

- If 0xD is specified as imm4 of the sbf instruction, the following message is output, and assembly is stopped.

```
E0550261 : illegal condition code.
```

mulh

Multiplies half-word.

[Syntax]

- mulh reg1, reg2
- mulh imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 16 bits[Note]
- Relative expression

Note The assembler does not check whether the value of the expression exceeds 16 bits. The generated mulh instruction performs the operation by using the lower 16 bits.

[Function]

- Syntax "mulh reg1, reg2"
  Multiplies the value of the lower halfword data of the register specified by the first operand by the value of the lower halfword data of the register specified by the second operand as a signed value, and stores the result in the register specified by the second operand.
- Syntax "mulh imm, reg2"
  Multiplies the value of the lower halfword data of the absolute expression or relative expression specified by the first operand by the value of the lower halfword data of the register specified by the second operand as a signed value, and stores the result in the register specified by the second operand.

[Description]

- If the instruction is executed in syntax "mulh reg1, reg2", the assembler generates one mulh machine instruction.
- If the following is specified as imm in syntax "mulh imm, reg2", the assembler generates one mulh machine instruction[Note].

(a) Absolute expression having a value in the range of -16 to +15

`mulh imm5, reg`	`mulh imm5, reg`

Note The mulh machine instruction takes a register or immediate value in the range of -16 to +15 (0xFFFFFFF0 to 0xF) as the first operand.

- If the following is specified for imm in syntax "mulh imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`mulh imm16, reg`	`mulhi imm16, reg, reg`

(b) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`mulh imm, reg`	`movhi HIGHW(imm), r0, r1` `mulh r1, reg`

Else

`mulh imm, reg`	`mov imm, r1` `mulh r1, reg`

(c) Relative expression having !label or %label, or that having $label for a label with a definition in the sdata/sbss-attribute section

`mulh !label, reg`	`mulhi !label, reg, reg`
`mulh %label, reg`	`mulhi %label, reg, reg`
`mulh $label, reg`	`mulhi $label, reg, reg`

(d) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`mulh #label, reg`	`mov #label, r1` `mulh r1, reg`
`mulh label, reg`	`mov label, r1` `mulh r1, reg`
`mulh $label, reg`	`mov $label, r1` `mulh r1, reg`

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If r0 is specified by the second operand, the assembler outputs the following message and stops assembling.

E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

mulhi

Multiplies half-word Immediate.

[Syntax]

- mulhi imm, reg1, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 16 bits[Note]
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

Note The assembler does not check whether the value of the expression exceeds 16 bits. The generated mulhi machine instruction performs the operation by using the lower 16 bits.

[Function]

Multiplies the value of the absolute expression, relative expression, or expression with HIGHW, LOWW, or HIGHW1 applied specified by the first operand by the value of the register specified by the second operand, and stores the result in the register specified by the third operand.

[Description]

- If the following is specified for imm, the assembler generates one mulhi machine instruction[Note].

(a) Absolute expression having a value in the range of -32,768 to +32,767

`mulhi imm16, reg1, reg2`	`mulhi imm16, reg1, reg2`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`mulhi $label, reg1, reg2`	`mulhi $label, reg1, reg2`

(c) Relative expression having !label or %label

`mulhi !label, reg1, reg2`	`mulhi !label, reg1, reg2`
`mulhi %label, reg1, reg2`	`mulhi %label, reg1, reg2`

(d) Expression with HIGHW, LOWW, or HIGHW1

`mulhi imm16, reg1, reg2`	`mulhi imm16, reg1, reg2`

Note The mulhi machine instruction takes an immediate value in the range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF) as the first operand.

- If the following is specified for imm, the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`mulhi imm, reg1, reg2`	`movhi HIGHW(imm), r0, reg2` `mulh reg1, reg2`

Else

`mulhi imm, reg1, reg2`	`mov imm, reg2` `mulh reg1, reg2`

(b) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`mulhi #label, reg1, reg2`	`mov #label, reg2` `mulh reg1, reg2`
`mulhi label, reg1, reg2`	`mov label, reg2` `mulh reg1, reg2`
`mulhi $label, reg1, reg2`	`mov $label, reg2` `mulh reg1, reg2`

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If r0 is specified by the third operand, the assembler outputs the following message and stops assembling.

E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

mul

Multiplies word.

[Syntax]

- mul reg1, reg2, reg3
- mul imm, reg2, reg3

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "mul reg1, reg2, reg3"
  Multiplies the register value specified by the first operand by the register value specified by the second operand as a signed value and stores the lower 32 bits of the result in the register specified by the second operand, and the higher 32 bits in the register specified by the third operand. If the same register is specified by the second and third operands, the higher 32 bits of the multiplication result are stored in that register.
- Syntax "mul imm, reg2, reg3"
  Multiplies the value of the absolute or relative expression specified by the first operand by the register value specified by the second operand as a signed value and stores the lower 32 bits of the result in the register specified by the second operand, and the higher 32 bits in the register specified by the third operand. If the same register is specified by the second and third operands, the higher 32 bits of the multiplication result are stored in that register.

[Description]

- If the instruction is executed in syntax "mul reg1, reg2, reg3", the assembler generates one mul machine instruction.
- If the instruction is executed in syntax "mul imm, reg2, reg3", the assembler executes instruction expansion to generate one or more machine instructions.

(a) 0

`mul 0, reg2, reg3`	`mul r0, reg2, reg3`

(b) Absolute expression having a value of other than 0 whithin the range of -256 to +255

`mul imm9, reg2, reg3`	`mul imm9, reg2, reg3`

(c) Absolute expression exceeding the range of -256 to +255, but within the range of -32,768 to +32,767

`mul imm16, reg2, reg3`	`movea imm16, r0, r1` `mul r1, reg2, reg3`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`mul imm, reg2, reg3`	`movhi HIGHW(imm), r0, r1` `mul r1, reg2, reg3`

Else

`mul imm, reg2, reg3`	`mov imm, r1` `mul r1, reg2, reg3`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`mul $label, reg2, reg3`	`movea $label, r0, r1` `mul r1, reg2, reg3`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`mul #label, reg2, reg3`	`mov #label, r1` `mul r1, reg2, reg3`
`mul label, reg2, reg3`	`mov label, r1` `mul r1, reg2, reg3`
`mul $label, reg2, reg3`	`mov $label, r1` `mul r1, reg2, reg3`

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

mulu

Multiplies unsigned word.

[Syntax]

- mulu reg1, reg2, reg3
- mulu imm, reg2, reg3

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "mulu reg1, reg2, reg3"
  Multiplies the register value specified by the first operand by the register value specified by the second operand as an unsigned value and stores the lower 32 bits of the result in the register specified by the second operand, and the higher 32 bits in the register specified by the third operand. If the same register is specified by the second and third operands, the higher 32 bits of the multiplication result are stored in that register.
- Syntax "mulu imm, reg2, reg3"
  Multiplies the value of the absolute or relative expression specified by the first operand by the register value specified by the second operand as an unsigned value and stores the lower 32 bits of the result in the register specified by the second operand, and the higher 32 bits in the register specified by the third operand. If the same register is specified by the second and third operands, the higher 32 bits of the multiplication result are stored in that register.

[Description]

- If the instruction is executed in syntax "mulu reg1, reg2, reg3", the assembler generates one mulu machine instruction.
- If the instruction is executed in syntax "mulu imm, reg2, reg3", the assembler executes instruction expansion to generate one or more machine instructions.

(a) 0

`mulu 0, reg2, reg3`	`mulu r0, reg2, reg3`

(b) Absolute expression having a value of other than 0 whithin the range of 0 to 511

`mulu imm9, reg2, reg3`	`mulu imm9, reg2, reg3`

(c) Absolute expression exceeding the range of -256 to +255, but within the range of -32,768 to +32,767

`mulu imm16, reg2, reg3`	`movea imm16, r0, r1` `mulu r1, reg2, reg3`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`mulu imm, reg2, reg3`	`movhi HIGHW(imm), r0, r1` `mulu r1, reg2, reg3`

Else

`mulu imm, reg2, reg3`	`mov imm, r1` `mulu r1, reg2, reg3`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`mulu $label, reg2, reg3`	`movea $label, r0, r1` `mulu r1, reg2, reg3`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`mulu #label, reg2, reg3`	`mov #label, r1` `mulu r1, reg2, reg3`
`mulu label, reg2, reg3`	`mov label, r1` `mulu r1, reg2, reg3`
`mulu $label, reg2, reg3`	`mov $label, r1` `mulu r1, reg2, reg3`

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

mac

Multiplies and adds signed word data.

[Syntax]

- mac reg1, reg2, reg3, reg4

[Function]

Adds the multiplication result of the general-purpose register reg2 word data and the general-purpose register reg1 word data with the 64-bit data made up of general-purpose register reg3 as the lower 32 bits and general-purpose register reg3+1 (for example, if reg3 were r6, "reg3+1" would be r7) as the upper 32 bits, and stores the upper 32 bits of that result (64-bit data) in general-purpose register reg4+1 and the lower 32 bits in general-purpose register reg4.

The contents of general-purpose registers reg1 and reg2 are treated as 32-bit signed integers.

General-purpose registers reg1, reg2, reg3, and reg3+1 are unaffected.

[Description]

The assembler generates one mac machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- The general-purpose registers that can be specified to reg3 or reg4 are limited to even numbered registers (r0, r2, r4, ..., r30). When specifying an odd numbered register, the following message is output, and assembly continues, specifying the register as an even numbered register (r0, r2, r4, ..., r30).

```
W0550026 : illegal register number, aligned odd register(rXX) to be even register(rYY).
```

macu

Multiply and adds unsigned word data.

[Syntax]

- macu reg1, reg2, reg3, reg4

[Function]

Adds the multiplication result of the general-purpose register reg2 word data and the general-purpose register reg1 word data with the 64-bit data made up of general-purpose register reg3 as the lower 32 bits and general-purpose register reg3+1 (for example, if reg3 were r6, "reg3+1" would be r7) as the upper 32 bits, and stores the upper 32 bits of that result (64-bit data) in general-purpose register reg4+1 and the lower 32 bits in general-purpose register reg4.

The contents of general-purpose registers reg1 and reg2 are treated as 32-bit unsigned integers.

General-purpose registers reg1, reg2, reg3, and reg3+1 are unaffected.

[Description]

The assembler generates one macu machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- The general-purpose registers that can be specified to reg3 or reg4 are limited to even numbered registers (r0, r2, r4, ..., r30). When specifying an odd numbered register, the following message is output, and assembly continues, specifying the register as an even numbered register (r0, r2, r4, ..., r30).

```
W0550026 : illegal register number, aligned odd register(rXX) to be even register(rYY).
```

divh

Divides half-word.

[Syntax]

- divh reg1, reg2
- divh imm, reg2
- divh reg1, reg2, reg3
- divh imm, reg2, reg3

The following can be specified for imm:

- Absolute expression having a value of up to 16 bits[Note]
- Relative expression

Note The assembler does not check whether the value of the expression exceeds 16 bits. The generated machine instruction performs execution using the lower 16 bits.

[Function]

- Syntax "divh reg1, reg2"
  Divides the register value specified by the second operand by the value of the lower halfword data of the register specified by the first operand as a signed value, and stores the quotient in the register specified by the second operand.
- Syntax "divh imm, reg2"
  Divides the register value specified by the second operand by the value of the lower halfword data of the absolute or relative expression specified by the first operand as a signed value and stores the quotient in the register specified by the second operand.
- Syntax "divh reg1, reg2, reg3"
  Divides the register value specified by the second operand by the value of the lower halfword data of the register specified by the first operand as a signed value and stores the quotient in the register specified by the second operand, and the remainder in the register specified by the third operand. If the same register is specified by the second and third operands, the remainder is stored in that register.
- Syntax "divh imm, reg2, reg3"
  Divides the register value specified by the second operand by the value of the lower halfword data of the absolute or relative expression specified by the first operand as a signed value and stores the quotient in the register specified by the second operand, and the remainder in the register specified by the third operand. If the same register is specified by the second and third operands, the remainder is stored in that register.

[Description]

- If the instruction is executed in syntaxes "divh reg1, reg2" and "divh reg1, reg2, reg3", the assembler generates one divh machine instruction.
- If the instruction is executed in syntax "divh imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions[Note].

(a) Absolute expression having a value of other than 0 within the range of -16 to +15

`divh imm5, reg`	`mov imm5, r1` `divh r1, reg`

(b) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`divh imm16, reg`	`movea imm16, r0, r1` `divh r1, reg`

(c) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`divh imm, reg`	`movhi HIGHW(imm), r0, r1` `divh r1, reg`

Else

`divh imm, reg`	`mov imm, r1` `divh r1, reg`

(d) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`divh $label, reg`	`movea $label, r0, r1` `divh r1, reg`

(e) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`divh #label, reg`	`mov #label, r1` `divh r1, reg`
`divh label, reg`	`mov label, r1` `divh r1, reg`
`divh $label, reg`	`mov $label, r1` `divh r1, reg`

Note The divh machine instruction does not take an immediate value as an operand.

- If the instruction is executed in syntax "divh imm, reg2, reg3", the assembler executes instruction expansion to generate one or more machine instructions.

(a) 0

`divh 0, reg2, reg3`	`divh r0, reg2, reg3`

(b) Absolute expression having a value of other than 0 within the range of -16 to +15

`divh imm5, reg2, reg3`	`mov imm5, r1` `divh r1, reg2, reg3`

(c) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`divh imm16, reg2, reg3`	`movea imm16, r0, r1` `divh r1, reg2, reg3`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`divh imm, reg2, reg3`	`movhi HIGHW(imm), r0, r1` `divh r1, reg2, reg3`

Else

`divh imm, reg2, reg3`	`mov imm, r1` `divh r1, reg2, reg3`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`divh $label, reg2, reg3`	`movea $label, r0, r1` `divh r1, reg2, reg3`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`divh #label, reg2, reg3`	`mov #label, r1` `divh r1, reg2, reg3`
`divh label, reg2, reg3`	`mov label, r1` `divh r1, reg2, reg3`
`divh $label, reg2, reg3`	`mov $label, r1` `divh r1, reg2, reg3`

[Flag]

CY	---
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

[Caution]

- If r0 is specified by the first operand in syntax "divh reg1, reg2", the assembler outputs the following message and stops assembling.

E0550239 : Illegal operand (cannot use r0 as source in RH850 mode).
E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

- If r0 is specified by the second operand (reg2) in syntaxes "divh imm, reg2", the assembler outputs the message and stops assembling.

E0550239 : Illegal operand (cannot use r0 as source in RH850 mode).
E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

- If 0 is specified by the second operand (imm) in syntaxes "divh imm, reg2", the assembler outputs the message and stops assembling.

E0550239 : Illegal operand (cannot use r0 as source in RH850 mode).

div

Divides word.

[Syntax]

- div reg1, reg2, reg3
- div imm, reg2, reg3

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "div reg1, reg2, reg3"

  Divides the register value specified by the second operand by the register value specified by the first operand as a signed value and stores the quotient in the register specified by the second operand, and the remainder in the register specified by the third operand. If the same register is specified by the second and third operands, the remainder is stored in that register.
- Syntax "div imm, reg2, reg3"

  Divides the register value specified by the second operand by the value of the absolute or relative expression specified by the first operand as a signed value and stores the quotient in the register specified by the second operand, and the remainder in the register specified by the third operand. If the same register is specified by the second and third operands, the remainder is stored in that register.

[Description]

- If the instruction is executed in syntax "div reg1, reg2, reg3", the assembler generates one div machine instruction.
- If the instruction is executed in syntax "div imm, reg2, reg3", the assembler executes instruction expansion to generate two or more machine instructions[Note].

(a) 0

`div 0, reg2, reg3`	`div r0, reg2, reg3`

(b) Absolute expression having a value of other than 0 within the range of -16 to +15

`div imm5, reg2, reg3`	`mov imm5, r1` `div r1, reg2, reg3`

(c) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`div imm16, reg2, reg3`	`movea imm16, r0, r1` `div r1, reg2, reg3`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`div imm, reg2, reg3`	`movhi HIGHW(imm), r0, r1` `div r1, reg2, reg3`

Else

`div imm, reg2, reg3`	`mov imm, r1` `div r1, reg2, reg3`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`div $label, reg2, reg3`	`movea $label, r0, r1` `div r1, reg2, reg3`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`div #label, reg2, reg3`	`mov #label, r1` `div r1, reg2, reg3`
`div label, reg2, reg3`	`mov label, r1` `div r1, reg2, reg3`
`div $label, reg2, reg3`	`mov $label, r1` `div r1, reg2, reg3`

Note The div machine instruction does not take an immediate value as an operand.

[Flag]

CY	---
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

divhu

Divides unsigned half-word.

[Syntax]

- divhu reg1, reg2, reg3
- divhu imm, reg2, reg3

The following can be specified for imm:

- Absolute expression having a value of up to 16 bits[Note]
- Relative expression

Note The assembler does not check whether the value of the expression exceeds 16 bits. The generated machine instruction uses only the lower 16 bits for execution.

[Function]

- Syntax "divhu reg1, reg2, reg3"
  Divides the register value specified by the second operand by the value of the lower halfword data of the register value specified by the first operand as an unsigned value and stores the quotient in the register specified by the second operand, and the remainder in the register specified by the third operand. If the same register is specified by the second and third operands, the remainder is stored in that register.
- Syntax "divhu imm, reg2, reg3"
  Divides the register value specified by the second operand by the value of the lower halfword data of the absolute or relative expression specified by the first operand as an unsigned value and stores the quotient in the register specified by the second operand, and the remainder in the register specified by the third operand. If the same register is specified by the second and third operands, the remainder is stored in that register.

[Description]

- If the instruction is executed in syntax "divhu reg1, reg2, reg3", the assembler generates one divhu machine instruction.
- If the instruction is executed in syntax "divhu imm, reg2, reg3", the assembler executes instruction expansion to generate one or more machine instructions[Note].

(a) 0

`divhu 0, reg2, reg3`	`divhu r0, reg2, reg3`

(b) Absolute expression having a value of other than 0 within the range of -16 to +15

`divhu imm5, reg2, reg3`	`mov imm5, r1` `divhu r1, reg2, reg3`

(c) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`divhu imm16, reg2, reg3`	`movea imm16, r0, r1` `divhu r1, reg2, reg3`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`divhu imm, reg2, reg3`	`movhi HIGHW(imm), r0, r1` `divhu r1, reg2, reg3`

Else

`divhu imm, reg2, reg3`	`mov imm, r1` `divhu r1, reg2, reg3`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`divhu $label, reg2, reg3`	`movea $label, r0, r1` `divhu r1, reg2, reg3`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`divhu #label, reg2, reg3`	`mov #label, r1` `divhu r1, reg2, reg3`
`divhu label, reg2, reg3`	`mov label, r1` `divhu r1, reg2, reg3`
`divhu $label, reg2, reg3`	`mov $label, r1` `divhu r1, reg2, reg3`

Note The divhu machine instruction does not take an immediate value as an operand.

[Flag]

CY	---
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

divu

Divides unsigned word.

[Syntax]

- divu reg1, reg2, reg3
- divu imm, reg2, reg3

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "divu reg1, reg2, reg3"
  Divides the register value specified by the second operand by the register value specified by the first operand as an unsigned value and stores the quotient in the register specified by the second operand, and the remainder in the register specified by the third operand. If the same register is specified by the second and third operands, the remainder is stored in that register.
- Syntax "divu imm, reg2, reg3"
  Divides the register value specified by the second operand by the value of the absolute or relative expression specified by the first operand as an unsigned value and stores the quotient in the register specified by the second operand, and the remainder in the register specified by the third operand. If the same register is specified by the second and third operands, the remainder is stored in that register.

[Description]

- If the instruction is executed in syntax "divu reg1, reg2, reg3", the assembler generates one divu machine instruction.
- If the instruction is executed in syntax "divu imm, reg2, reg3", the assembler executes instruction expansion to generate one or more machine instructions[Note].

(a) 0

`divu 0, reg2, reg3`	`divu r0, reg2, reg3`

(b) Absolute expression having a value of other than 0 whithin the range of -16 to +15

`divu imm5, reg2, reg3`	`mov imm5, r1` `divu r1, reg2, reg3`

(c) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`divu imm16, reg2, reg3`	`movea imm16, r0, r1` `divu r1, reg2, reg3`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`divu imm, reg2, reg3`	`movhi HIGHW(imm), r0, r1` `divu r1, reg2, reg3`

Else

`divu imm, reg2, reg3`	`mov imm, r1` `divu r1, reg2, reg3`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`divu $label, reg2, reg3`	`movea $label, r0, r1` `divu r1, reg2, reg3`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`divu #label, reg2, reg3`	`mov #label, r1` `divu r1, reg2, reg3`
`divu label, reg2, reg3`	`mov label, r1` `divu r1, reg2, reg3`
`divu $label, reg2, reg3`	`mov $label, r1` `divu r1, reg2, reg3`

Note The divu machine instruction does not take an immediate value as an operand.

[Flag]

CY	---
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

divq

Division of (signed) word data (variable steps) (Divide Word Quickly)

[Syntax]

- divq reg1, reg2, reg3

[Function]

Divides the word data in general-purpose register reg2 by the word data in general-purpose register reg1, stores the quotient in reg2, and stores the remainder in general-purpose register reg3. General-purpose register reg1 is not affected.

The minimum number of steps required for division is determined from the values in reg1 and reg2, then this operation is executed.

When division by zero occurs, an overflow results and all operation results except for the OV flag are undefined.

[Description]

- The assembler generates one divq machine instruction.

[Flag]

CY	---
OV	"1" when overflow occurs; otherwise, "0"
S	"1" when operation result quotient is a negative value; otherwise, "0"
Z	"1" when operation result quotient is a "0"; otherwise, "0"
SAT	---

divqu

Division of (unsigned) word data (variable steps) (Divide Word Unsigned Quickly)

[Syntax]

- divqu reg1, reg2, reg3

[Function]

Divides the word data in general-purpose register reg2 by the word data in general-purpose register reg1, stores the quotient in reg2, and stores the remainder in general-purpose register reg3. General-purpose register reg1 is not affected.

The minimum number of steps required for division is determined from the values in reg1 and reg2, then this operation is executed.

When division by zero occurs, an overflow results and all operation results except for the OV flag are undefined.

[Description]

- The assembler generates one divqu machine instruction.

[Flag]

CY	---
OV	"1" when overflow occurs; otherwise, "0"
S	"1" when the MSB in the word data of the operation result quotient is a negative value; otherwise, "0"
Z	"1" when operation result quotient is a "0"; otherwise, "0"
SAT	---

cmp

Compares.

[Syntax]

- cmp reg1, reg2
- cmp imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "cmp reg1, reg2"
  Compares the value of the register specified by the first operand with the value of the register specified by the second operand, and indicates the result using a flag. Comparison is performed by subtracting the value of the register specified by the first operand from the value of the register specified by the second operand.
- Syntax "cmp imm, reg2"
  Compares the value of the absolute expression or relative expression specified by the first operand with the value of the register specified by the second operand, and indicates the result using a flag. Comparison is performed by subtracting the value of the register specified by the first operand from the value of the register specified by the second operand.

[Description]

- If the instruction is executed in syntax "cmp reg1, reg2", the assembler generates one cmp machine instruction.
- If the following is specified as imm in syntax "cmp imm, reg2", the assembler generates one cmp machine instruction[Note].

(a) Absolute expression having a value in the range of -16 to +15

`cmp imm5, reg`	`cmp imm5, reg`

Note The cmp machine instruction takes a register or immediate value in the range of -16 to +15 (0xFFFFFFF0 to 0xF) as the first operand.

- If the following is specified as imm in syntax "cmp imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`cmp imm16, reg`	`movea imm16, r0, r1` `cmp r1, reg`

(b) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`cmp imm, reg`	`movhi HIGHW(imm), r0, r1` `cmp r1, reg`

Else

`cmp imm, reg`	`mov imm, r1` `cmp r1, reg`

(c) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`cmp $label, reg`	`movea $label, r0, r1` `cmp r1, reg`

(d) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`cmp #label, reg`	`mov #label, r1` `cmp r1, reg`
`cmp label, reg`	`mov label, r1` `cmp r1, reg`
`cmp $label, reg`	`mov $label, r1` `cmp r1, reg`

[Flag]

CY	1 if a borrow occurs from MSB (Most Significant Bit),0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

mov

Moves.

[Syntax]

- mov reg1, reg2
- mov imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "mov reg1, reg2"
  Stores the value of the register specified by the first operand in the register specified by the second operand.
- Syntax "mov imm, reg2"
  Stores the value of the absolute expression or relative expression specified by the first operand in the register specified by the second operand.

[Description]

- If the instruction is executed in syntax "mov reg1, reg2", the assembler generates one mov machine instruction.
- If the following is specified as imm in syntax "mov imm, reg2", the assembler generates one mov machine instruction[Note].

(a) Absolute expression having a value in the range of -16 to +15

`mov imm5, reg`	`mov imm5, reg`

Note The mov machine instruction takes a register or immediate value in the range of -16 to +15 (0xFFFFFFF0 to 0xF) as the first operand.

- If the following is specified as imm in syntax "mov imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`mov imm16, reg`	`movea imm16, r0, reg`

(b) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`mov imm, reg`	`movhi HIGHW(imm), r0, reg`

Else[Note]

`mov imm, reg`	`mov imm, reg`

Note A 16-bit mov instruction is replaced by a 48-bit mov instruction.

(c) Relative expression having !label or %label, or that having $label for a label with a definition in the sdata/sbss-attribute section

`mov !label, reg`	`movea !label, r0, reg`
`mov %label, reg`	`movea %label, r0, reg`
`mov $label, reg`	`movea $label, r0, reg`

(d) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section[Note]

`mov #label, reg`	`mov #label, reg`
`mov label, reg`	`mov label, reg`
`mov $label, reg`	`mov $label, reg`

Note A 16-bit mov instruction is replaced by a 48-bit mov instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value in the range between -16 and 15 is specified by the first operand and r0 is specified by the second operand of syntax "mov imm, reg2", or r0 is specified by the second operand of syntax "mov reg1, reg2", the assembler outputs the following message and stops assembling.

```
E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).
```

- For the "mov imm, reg2" instruction, if an absolute expression exceeding the range of -32768 to 32767, a relative expression with a #label or label, and a relative expression with label $label without a definition in an sdata/sbss attribute section is specified in the first operand, then the assembler performs instruction expansion, and converts the 16-bit mov instruction into a 48-bit mov instruction. If you prevent instruction expansion using the .option nomacro directive and this instruction expansion occurs, then the following message is output, and the assembler halts.

```
E0550249 : illegal syntax
```

movea

Moves execution address.

[Syntax]

- movea imm, reg1, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

[Function]

Adds the value of the absolute expression, relative expression, or expression with HIGHW, LOWW, or HIGHW1 applied, specified by the first operand, to the value of the register specified by the second operand, and stores the result in the register specified by the third operand.

[Description]

- If the following is specified for imm, the assembler generates one movea machine instruction[Note].
- If r0 is specified by reg1, the assembler recognizes specified syntax "mov imm, reg2".

(a) Absolute expression having a value in the range of -32,768 to +32,767

`movea imm16, reg1, reg2`	`movea imm16, reg1, reg2`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`movea $label, reg1, reg2`	`movea $label, reg1, reg2`

(c) Relative expression having !label or %label

`movea !label, reg1, reg2`	`movea !label, reg1, reg2`
`movea %label, reg1, reg2`	`movea %label, reg1, reg2`

(d) Expression with HIGHW, LOWW, or HIGHW1

`movea imm16, reg1, reg2`	`movea imm16, reg1, reg2`

Note The movea machine instruction takes an immediate value in a range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF) as the first operand.

- If the following is specified for imm, the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`movea imm, reg1, reg2`	`movhi HIGHW(imm), reg1, reg2`

Else

`movea imm, reg1, reg2`	`movhi HIGHW1(imm), reg1, r1` `movea LOWW(imm), r1, reg2`

(b) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`movea #label, reg1, reg2`	`movhi HIGHW1(#label), reg1, r1` `movea LOWW(#label), r1, reg2`
`movea label, reg1, reg2`	`movhi HIGHW1(label), reg1, r1` `movea LOWW(label), r1, reg2`
`movea $label, reg1, reg2`	`movhi HIGHW1($label), reg1, r1` `movea LOWW($label), r1, reg2`

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If r0 is specified by the third operand, the assembler outputs the following message and stops assembling.

E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

movhi

Moves higher half-word.

[Syntax]

- movhi imm16, reg1, reg2

The following can be specified for imm16:

- Absolute expression having a value of up to 16 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

[Function]

Adds word data for which the higher 16 bits are specified by the first operand and the lower 16 bits are 0, to the value of the register specified by the second operand, and stores the result in the register specified by the third operand.

[Description]

The assembler generates one movhi machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of 0 to 65,535 is specified as imm16, the assembler outputs the following message and stops assembling.

```
E0550231 : illegal operand (range error in immediate)
```

- If r0 is specified by the third operand, the assembler outputs the following message and stops assembling.

```
E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).
```

mov32

Moves 32-bit data.

[Syntax]

- mov32 imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression[Note]

Note If the operand is a relative expression, HIGHW, LOWW, and HIGHW1 cannot be used.

[Function]

Stores the value of the absolute or relative expression specified as the first operand in the register specified as the second operand.

[Description]

The assembler generates one 48-bit machine language mov instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

cmov

Moves data depending on the flag condition.

[Syntax]

- cmov imm4, reg1, reg2, reg3
- cmov imm4, imm, reg2, reg3
- cmov*cnd* reg1, reg2, reg3
- cmov*cnd* imm, reg2, reg3

The following can be specified for imm4:

- Absolute expression having a value up to 4 bits[Note]

Note The cmov machine instruction takes an immediate value in the range of 0 to 15 (0x0 to 0xF) as the first operand.

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "cmov imm4, reg1, reg2, reg3"
  Compares the flag condition indicated by the value of the lower 4 bits of the value of the constant expression specified by the first operand with the current flag condition. If a match is found, the register value specified by the second operand is stored in the register specified by the fourth operand; otherwise, the register value specified by the third operand is stored in the register specified by the fourth operand.
- Syntax "cmov imm4, imm, reg2, reg3"
  Compares the flag condition indicated by the value of the lower 4 bits of the constant expression specified by the first operand with the current flag condition. If a match is found, the value of the absolute expression specified by the second operand is stored in the register specified by the fourth operand; otherwise, the register value specified by the third operand is stored in the register specified by the fourth operand.
- Syntax "cmov*cnd* reg1, ret2, reg3"
  Compares the flag condition indicated by string *cnd* with the current flag condition. If a match is found, the register value specified by the first operand is stored in the register specified by the third operand; otherwise, the register value specified by the second operand is stored in the register specified by the third operand.
- Syntax "cmov*cnd* imm, reg2, reg3"
  Compares the flag condition indicated by string *cnd* with the current flag condition. If a match is found, the value of the absolute expression specified by the first operand is stored in the register specified by the third operand; otherwise, the register value specified by the second operand is stored in the register specified by the third operand.

Table 4-30. cmov*cnd* Instruction List

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
cmovgt	((S xor OV) or Z) = 0	Greater than (signed)	cmov 0xF
cmovge	(S xor OV) = 0	Greater than or equal (signed)	cmov 0xE
cmovlt	(S xor OV) = 1	Less than (signed)	cmov 0x6
cmovle	((S xor OV) or Z) = 1	Less than or equal (signed)	cmov 0x7
cmovh	(CY or Z) = 0	Higher (Greater than)	cmov 0xB

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
cmovnl	CY = 0	Not lower (Greater than or equal)	cmov 0x9
cmovl	CY = 1	Lower (Less than)	cmov 0x1
cmovnh	(CY or Z) = 1	Not higher (Less than or equal)	cmov 0x3
cmove	Z = 1	Equal	cmov 0x2
cmovne	Z = 0	Not equal	cmov 0xA
cmovv	OV = 1	Overflow	cmov 0x0
cmovnv	OV = 0	No overflow	cmov 0x8
cmovn	S = 1	Negative	cmov 0x4
cmovp	S = 0	Positive	cmov 0xC
cmovc	CY = 1	Carry	cmov 0x1
cmovnc	CY = 0	No carry	cmov 0x9
cmovz	Z = 1	Zero	cmov 0x2
cmovnz	Z = 0	Not zero	cmov 0xA
cmovt	always 1	Always 1	cmov 0x5
cmovsa	SAT = 1	Saturated	cmov 0xD

[Description]

- If the instruction is executed in syntax "cmov imm4, reg1, reg2, reg3", the assembler generates one cmov machine instruction[Note].

Note The cmov machine instruction takes a register or immediate value in the range of -16 to +15 (0xFFFFFFF0 to 0xF) as the second operand.

- If the following is specified as imm in syntax "cmov imm4, imm, reg2, reg3", the assembler generates one cmov machine instruction.

(a) Absolute expression having a value in the range of -16 to +15

`cmov imm4, imm5, reg2, reg3`	`cmov imm4, imm5, reg2, reg3`

- If the following is specified as imm in syntax "cmov imm4, imm, reg2, reg3", the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`cmov imm4, imm16, reg2, reg3`	`movea imm16, r0, r1` `cmov imm4, r1, reg2, reg3`

(b) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`cmov imm4, imm, reg2, reg3`	`movhi HIGHW(imm), r0, r1` `cmov imm4, r1, reg2, reg3`

Else

`cmov imm4, imm, reg2, reg3`	`mov imm, r1` `cmov imm4, r1, reg2, reg3`

(c) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`cmov imm4, #label, reg2, reg3`	`mov #label, r1` `cmov imm4, r1, reg2, reg3`
`cmov imm4, label, reg2, reg3`	`mov label, r1` `cmov imm4, r1, reg2, reg3`
`cmov imm4, $label, reg2, reg3`	`mov $label, r1` `cmov imm4, r1, reg2, reg3`

(d) Relative expression having !label or %label, or that having $label for a label with a definition in the sdata/sbss-attribute section

`cmov imm4, !label, reg2, reg3`	`movea !label, r0, r1` `cmov imm4, r1, reg2, reg3`
`cmov imm4, %label, reg2, reg3`	`movea %label, r0, r1` `cmov imm4, r1, reg2, reg3`
`cmov imm4, $label, reg2, reg3`	`movea $label, r0, r1` `cmov imm4, r1, reg2, reg3`

- If the instruction is executed in syntax "cmov*cnd* reg1, ret2, reg3", the assembler generates the corresponding cmov instruction (see "Table 4-30. cmovcnd Instruction List") and expands it to syntax "cmov imm4, reg1, reg2, reg3".
- If the following is specified as imm in syntax "cmov*cnd* imm, reg2, reg3", the assembler generates the corresponding cmov instruction (see "Table 4-30. cmovcnd Instruction List") and expands it to syntax "cmov imm, reg2, reg3".

(a) Absolute expression having a value in the range of -16 to +15

- If the following is specified as imm in syntax "cmov*cnd* imm, reg2, reg3", the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`cmov`*`cnd`* `imm16, reg2, reg3`	`movea imm16, r0, r1` `cmov`*`cnd`* `r1, reg2, reg3`

(b) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

cmov*cnd* imm, reg2, reg3	movhi HIGHW(imm), r0, r1 cmov*cnd* r1, reg2, reg3

Else

cmov*cnd* imm, reg2, reg3	mov imm, r1 cmov*cnd* r1, reg2, reg3

(c) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

cmov*cnd* #label, reg2, reg3	mov #label, r1 cmov*cnd* r1, reg2, reg3
cmov*cnd* label, reg2, reg3	mov label, r1 cmov*cnd* r1, reg2, reg3
cmov*cnd* $label, reg2, reg3	mov $label, r1 cmov*cnd* r1, reg2, reg3

(d) Relative expression having !label or %label, or that having $label for a label with a definition in the sdata/sbss-attribute section

cmov*cnd* !label, reg2, reg3	movea !label, r0, r1 cmov*cnd* r1, reg2, reg3
cmov*cnd* %label, reg2, reg3	movea %label, r0, r1 cmov*cnd* r1, reg2, reg3
cmov*cnd* $label, reg2, reg3	movea $label, r0, r1 cmov*cnd* r1, reg2, reg3

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If a constant expression having a value exceeding 4 bits is specified as imm4 of the cmov instruction, the assembler outputs the following message.
  If the value exceeds 4 bits, the assembler masks the value with 0xF and continues assembling.

W0550011 : illegal operand (range error in immediate)

setf

Sets flag condition.

[Syntax]

- setf imm4, reg
- setf*cnd* reg

The following can be specified for imm4:

- Absolute expression having a value up to 4 bits

[Function]

- Syntax "setf imm4, reg"
  Compares the status of the flag specified by the value of the lower 4 bits of the absolute expression specified by the first operand with the current flag condition. If they are found to match, 1 is stored in the register specified by the second operand; otherwise, 0 is stored in the register specified by the second operand.
- Syntax "setf*cnd* reg"
  Compares the status of the flag indicated by string *cnd* with the current flag condition. If they are found to match, 1 is stored in the register specified by the second operand; otherwise, 0 is stored in the register specified by the second operand.

[Description]

- If the instruction is executed in syntax"setf imm4, reg",the assembler generates one satf machine instruction.
- If the instruction is executed in syntax "setf*cnd* reg", the assembler generates the corresponding setf instruction (see "Table 4-31. setfcnd Instruction List") and expands it to syntax "setf imm4, reg".

Table 4-31. setf*cnd* Instruction List

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
setfgt	((S xor OV) or Z) = 0	Greater than (signed)	setf 0xF
setfge	(S xor OV) = 0	Greater than or equal (signed)	setf 0xE
setflt	(S xor OV) = 1	Less than (signed)	setf 0x6
setfle	((S xor OV) or Z) = 1	Less than or equal (signed)	setf 0x7
setfh	(CY or Z) = 0	Higher (Greater than)	setf 0xB
setfnl	CY = 0	Not lower (Greater than or equal)	setf 0x9
setfl	CY = 1	Lower (Less than)	setf 0x1
setfnh	(CY or Z) = 1	Not higher (Less than or equal)	setf 0x3
setfe	Z = 1	Equal	setf 0x2
setfne	Z = 0	Not equal	setf 0xA
setfv	OV = 1	Overflow	setf 0x0
setfnv	OV = 0	No overflow	setf 0x8
setfn	S = 1	Negative	setf 0x4
setfp	S = 0	Positive	setf 0xC
setfc	CY = 1	Carry	setf 0x1

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
setfnc	CY = 0	No carry	setf 0x9
setfz	Z = 1	Zero	setf 0x2
setfnz	Z = 0	Not zero	setf 0xA
setft	always 1	Always 1	setf 0x5
setfsa	SAT = 1	Saturated	setf 0xD

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value exceeding 4 bits is specified as imm4 of the setf instruction, the assembler outputs the following message and continues assembling using four low-order bits of a specified value.

W0550011: illegal operand (range error in immediate).

sasf

Sets the flag condition after a logical left shift.

[Syntax]

- sasf imm4, reg
- sasf*cnd* reg

The following can be specified for imm4:

- Absolute expression having a value up to 4 bits

[Function]

- Syntax "sasf imm4, reg"
  Compares the flag condition indicated by the value of the lower 4 bits of the absolute expression specified by the first operand with the current flag condition. If a match is found, the contents of the register specified by the second operand are shifted logically 1 bit to the left and ORed with 1, and the result stored in the register specified by the second operand; otherwise, the contents of the register specified by the second operand are logically shifted 1 bit to the left and the result stored in the register specified by the second operand.
- Syntax "sasf*cnd* reg"
  Compares the flag condition indicated by string *cnd* with the current flag condition. If a match is found, the contents of the register specified by the second operand are shifted logically 1 bit to the left and ORed with 1, and the result stored in the register specified by the second operand; otherwise, the contents of the register specified by the second operand are shifted logically 1 bit to the left and the result stored in the register specified by the second operand.

[Description]

- If the instruction is executed in syntax "sasf imm4, reg", the assembler generates one sasf machine instruction.
- If the instruction is executed in syntax "sasf*cnd* reg", the assembler generates the corresponding sasf instruction (see "Table 4-32. sasfcnd Instruction List") and expands it to syntax "sasf imm4, reg".

Table 4-32. sasf*cnd* Instruction List

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
sasfgt	((S xor OV) or Z) = 0	Greater than (signed)	sasf 0xF
sasfge	(S xor OV) = 0	Greater than or equal (signed)	sasf 0xE
sasflt	(S xor OV) = 1	Less than (signed)	sasf 0x6
sasfle	((S xor OV) or Z) = 1	Less than or equal (signed)	sasf 0x7
sasfh	(CY or Z) = 0	Higher (Greater than)	sasf 0xB
sasfnl	CY = 0	Not lower (Greater than or equal)	sasf 0x9
sasfl	CY = 1	Lower (Less than)	sasf 0x1
sasfnh	(CY or Z) = 1	Not higher (Less than or equal)	sasf 0x3
sasfe	Z = 1	Equal	sasf 0x2
sasfne	Z = 0	Not equal	sasf 0xA
sasfv	OV = 1	Overflow	sasf 0x0
sasfnv	OV = 0	No overflow	sasf 0x8

Instruction	Flag Condition	Meaning of Flag Condition	Instruction Expansion
sasfn	S = 1	Negative	sasf 0x4
sasfp	S = 0	Positive	sasf 0xC
sasfc	CY = 1	Carry	sasf 0x1
sasfnc	CY = 0	No carry	sasf 0x9
sasfz	Z = 1	Zero	sasf 0x2
sasfnz	Z = 0	Not zero	sasf 0xA
sasft	always 1	Always 1	sasf 0x5
sasfsa	SAT = 1	Saturated	sasf 0xD

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value exceeding 4 bits is specified as imm4 of the sasf instruction, the assembler outputs the following message and continues assembling using four low-order bits of a specified value.

W0550011 : illegal operand (range error in immediate).

bins

Insert bit in register (Bitfield Insert)

[Syntax]

- bins reg1, pos, width, reg2

The following can be specified as ipos and width:

- Absolute expression having a value of up to 5 bits

[Function]

Loads the lower width bits in general-purpose register reg1 and stores them from the bit position bit pos + width - 1 in the specified field in general-purpose register reg2 in bit pos. This instruction does not affect any fields in general-purpose register reg2 except the specified field, nor does it affect general-purpose register reg1.

[Description]

- The assembler generates one bins machine instruction.

[Flag]

CY	---
OV	0
S	"1" if the word data MSB of the result is "1", otherwise, "0"
Z	"1" if the operation result is "0"; otherwise, "0"
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of 0 to 31 is specified as pos or width, the assembler outputs the following message.

```
W0550011 : Illegal operand (range error in immediate).
```

rotl

Rotate (Rotate Left)

[Syntax]

- rotl imm, reg2, reg3
- rotl reg1, reg2, reg3

The following can be specified as imm:

- Absolute expression having a value of up to 5 bits

[Function]

- Syntax "rotl imm, reg2, reg3"
  Rotates the word data of general-purpose register reg2 to the left by the specified shift amount, which is indicated by a 5-bit immediate value zero-extended to word length. The result is written to general-purpose register reg3. General-purpose register reg2 is not affected.
- Syntax "rotl reg1, reg2, reg3"
  Rotates the word data of general-purpose register reg2 to the left by the specified shift amount indicated by the lower 5 bits of general-purpose register reg1. The result is written to general-purpose register reg3. General-purpose registers reg1 and reg2 are not affected.

[Description]

- If the following is specified as imm in syntax "rotl imm, reg2, reg3", the assembler generates one rotl[Note] machine instruction.

(a) Absolute expression having a value in the range of 0 to 31

Note The rotl machine instruction takes a register or immediate value in the range of 0 to 31 (0 to 0x1F) as the first operand.

- Syntax "rotl reg1, reg2, reg3"
  The assembler generates one rotl machine instruction.

[Flag]

CY	"1" if operation result bit 0 is "1"; otherwise "0", including if the rotate amount is "0"
OV	0
S	"1" if the operation result is negative; otherwise, "0"
Z	"1" if the operation result is "0"; otherwise, "0"
SAT	---

4.8.3 Saturated operation instructions

This section describes the saturated operation instructions. Next table lists the instructions described in this section. See the RH850 product user's manual and architecture edition for details.

Table 4-33. Saturated Operation Instructions

Instruction	Meaning
satadd	Adds saturated
satsub	Subtracts saturated
satsubi	Subtracts saturated (immediate)
satsubr	Subtracts reverse saturated

satadd

Adda saturated.

[Syntax]

- satadd reg1, reg2
- satadd imm, reg2
- satadd reg1, reg2, reg3

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "satadd reg1, reg2"
  Adds the value of the register specified by the first operand to the value of the register specified by the second operand, and stores the result in the register specified by the second operand. If the result exceeds the maximum positive value of 0x7FFFFFFF, however, 0x7FFFFFFF is stored in the register specified by the second operand. Likewise, if the result exceeds the maximum negative value of 0x80000000, 0x80000000 is stored in the register specified by the second operand. In both cases, the SAT flag is set to 1.
- Syntax "satadd imm, reg2"
  Adds the value of the absolute expression or relative expression specified by the first operand to the value of the register specified by the second operand, and stores the result in the register specified by the second operand. If the result exceeds the maximum positive value of 0x7FFFFFFF, however, 0x7FFFFFFF is stored in the register specified by the second operand. Likewise, if the result exceeds the maximum negative value of 0x80000000, 0x80000000 is stored in the register specified by the second operand. In both cases, the SAT flag is set to 1.
- Syntax "satadd reg1, reg2, reg3"
  Adds the value of the register specified by the first operand to the value of the register specified by the second operand, and stores the result in the register specified by the third operand. If the result exceeds the maximum positive value of 0x7FFFFFFF, however, 0x7FFFFFFF is stored in the register specified by the second operand. Likewise, if the result exceeds the maximum negative value of 0x80000000, 0x80000000 is stored in the register specified by the third operand. In both cases, the SAT flag is set to 1.

[Description]

- If the instruction is executed in syntax "satadd reg1, reg2" or "satadd reg1, reg2, reg3", the assembler generates one satadd machine instruction.
- If the following is specified for imm in syntax "satadd imm, reg2", the assembler generates one satadd machine instruction[Note].

(a) Absolute expression having a value in the range of -16 to +15

`satadd imm5, reg`	`satadd imm5, reg`

Note The satadd machine instruction takes a register or immediate value in the range of -16 to +15 (0xFFFFFFF0 to 0xF) as the first operand.

- If the following is specified for imm in syntax "satadd imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`satadd imm16, reg`	`movea imm16, r0, r1` `satadd r1, reg`

(b) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`satadd imm, reg`	`movhi HIGHW(imm), r0, r1` `satadd r1, reg`

Else

`satadd imm, reg`	`mov imm, r1` `satadd r1, reg`

(c) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`satadd $label, reg`	`movea $label, r0, r1` `satadd r1, reg`

(d) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`satadd #label, reg`	`mov #label, r1` `satadd r1, reg`
`satadd label, reg`	`mov label, r1` `satadd r1, reg`
`satadd $label, reg`	`mov $label, r1` `satadd r1, reg`

[Flag]

CY	1 if a carry occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	1 if OV = 1, - if not

[Caution]

- If the instruction is executed in syntax "satadd reg1, reg2" or "satadd imm, reg2", if r0 is specified as the second operand, the assembler outputs the following message and stops assembling.

```
E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).
```

satsub

Subtracts saturated.

[Syntax]

- satsub reg1, reg2
- satsub imm, reg2
- satsub reg1, reg2, reg3

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "satsub reg1, reg2"
  Subtracts the value of the register specified by the first operand from the value of the register specified by the second operand, and stores the result in the register specified by the third operand. If the result exceeds the maximum positive value of 0x7FFFFFFF, however, 0x7FFFFFFF is stored in the register specified by the second operand. Likewise, if the result exceeds the maximum negative value of 0x80000000, 0x80000000 is stored in the register specified by the second operand. In both cases, the SAT flag is set to 1
- Syntax "satsub imm, reg2"
  Subtracts the value of the absolute expression or relative expression specified by the first operand from the value of the register specified by the second operand, and stores the result in the register specified by the second operand. If the result exceeds the maximum positive value of 0x7FFFFFFF, however, 0x7FFFFFFF is stored in the register specified by the second operand. Likewise, if the result exceeds the maximum negative value of 0x80000000, 0x80000000 is stored in the register specified by the second operand. In both cases, the SAT flag is set to 1.
- Syntax "satsub reg1, reg2, reg3"
  Subtracts the value of the register specified by the first operand from the value of the register specified by the second operand, and stores the result in the register specified by the second operand. If the result exceeds the maximum positive value of 0x7FFFFFFF, however, 0x7FFFFFFF is stored in the register specified by the second operand. Likewise, if the result exceeds the maximum negative value of 0x80000000, 0x80000000 is stored in the register specified by the third operand. In both cases, the SAT flag is set to 1.

[Description]

- If the instruction is executed in syntax "satsub reg1, reg2" or "satsub reg1, reg2, reg3", the assembler generates one satsub machine instruction.
- If the instruction is executed in syntax "satsub imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions[Note].

(a) 0

`satsub 0, reg`	`satsub r0, reg`

(b) Absolute expression having a value in the range of -32,768 to +32,767

`satsub imm16, reg`	`satsubi imm16, reg, reg`

(c) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`satsub imm, reg`	`movhi HIGHW(imm), r0, r1` `satsub r1, reg`

Else

`satsub imm, reg`	`mov imm, r1` `satsub r1, reg`

(d) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`satsub $label, reg`	`satsubi $label, reg, reg`

(e) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`satsub #label, reg`	`mov #label, r1` `satsub r1, reg`
`satsub label, reg`	`mov label, r1` `satsub r1, reg`
`satsub $label, reg`	`mov $label, r1` `satsub r1, reg`

Note The satsub machine instruction does not take an immediate value as an operand.

[Flag]

CY	1 if a borrow occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	1 if OV = 1, - if not

[Caution]

- If the instruction is executed in syntax "satsub reg1, reg2" or "satsub imm, reg2", if r0 is specified as the second operand, the assembler outputs the following message and stops assembling.

E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

satsubi

Subtracts saturated (immediate).

[Syntax]

- satsubi imm, reg1, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

[Function]

Subtracts the value of the absolute expression, relative expression, or expression with HIGHW, LOWW, or HIGHW1 applied specified by the first operand from the value of the register specified by the second operand, and stores the result in the register specified by the third operand. If the result exceeds the maximum positive value of 0x7FFFFFFF, however, 0x7FFFFFFF is stored in the register specified by the third operand. Likewise, if the result exceeds the maximum negative value of 0x80000000, 0x80000000 is stored in the register specified by the third operand. In both cases, the SAT flag is set to 1.

[Description]

- If the following is specified for imm, the assembler generates one satsubi machine instruction[Note].

(a) Absolute expression having a value in the range of -32,768 to +32,767

`satsubi imm16, reg1, reg2`	`satsubi imm16, reg1, reg2`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`satsubi $label, reg1, reg2`	`satsubi $label, reg1, reg2`

(c) Relative expression having !label or %label

`satsubi !label, reg1, reg2`	`satsubi !label, reg1, reg2`
`satsubi %label, reg1, reg2`	`satsubi %label, reg1, reg2`

(d) Expression with HIGHW, LOWW, or HIGHW1

`satsubi imm16, reg1, reg2`	`satsubi imm16, reg1, reg2`

Note The satsubi machine instruction takes an immediate value, in the range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF), as the first operand.

- If the following is specified for imm, the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

<1> If all the lower 16 bits of the value of imm are 0

`satsubi imm, reg1, reg2`	`movhi HIGHW(imm), r0, reg2` `satsubr reg1, reg2`

<2> Else

`satsubi imm, reg1, reg2`	`mov imm, reg2` `satsubr reg1, reg2`

(b) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`satsubi #label, reg1, reg2`	`mov #label, reg2` `satsubr reg1, reg2`
`satsubi label, reg1, reg2`	`mov label, reg2` `satsubr reg1, reg2`
`satsubi $label, reg1, reg2`	`mov $label, reg2` `satsubr reg1, reg2`

[Flag]

CY	1 if a borrow occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	1 if OV = 1, - if not

[Caution]

- If r0 is specified by the second operand, the assembler outputs the following message and stops assembling.

E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

satsubr

Subtracts reverse saturated.

[Syntax]

- satsubr reg1, reg2
- satsubr imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "satsubr reg1, reg2"
  Subtracts the value of the register specified by the second operand from the value of the register specified by the first operand, and stores the result in the register specified by the second operand. If the result exceeds the maximum positive value of 0x7FFFFFFF, however, 0x7FFFFFFF is stored in the register specified by the second operand. Likewise, if the result exceeds the maximum negative value of 0x80000000, 0x80000000 is stored in the register specified by the second operand. In both cases, the SAT flag is set to 1.
- Syntax "satsubr imm, reg2"
  Subtracts the value of the register specified by the second operand from the value of the absolute expression or relative expression specified by the first operand, and stores the result in the register specified by the second operand. If the result exceeds the maximum positive value of 0x7FFFFFFF, however, 0x7FFFFFFF is stored in the register specified by the second operand. Likewise, if the result exceeds the maximum negative value of 0x80000000, 0x80000000 is stored in the register specified by the second operand. In both cases, the SAT flag is set to 1.

[Description]

- If the instruction is executed in syntax "satsubr reg1, reg2", the assembler generates one satsubr machine instruction.
- If the instruction is executed in syntax "satsubr imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions[Note].

(a) 0

`satsubr 0, reg`	`satsubr r0, reg`

(b) Absolute expression having a value of other than 0 within the range of -16 to +15

`satsubr imm5, reg`	`mov imm5, r1` `satsubr r1, reg`

(c) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`satsubr imm16, reg`	`movea imm16, r0, r1` `satsubr r1, reg`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`satsubr imm, reg`	`movhi HIGHW(imm), r0, r1` `satsubr r1, reg`

Else

`satsubr imm, reg`	`mov imm, r1` `satsubr r1, reg`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`satsubr $label, reg`	`movea $label, r0, r1` `satsubr r1, reg`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`satsubr #label, reg`	`mov #label, r1` `satsubr r1, reg`
`satsubr label, reg`	`mov label, r1` `satsubr r1, reg`
`satsubr $label, reg`	`mov $label, r1` `satsubr r1, reg`

Note The satsubr machine instruction does not take an immediate value as an operand.

[Flag]

CY	1 if a borrow occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	1 if OV = 1, - if not

[Caution]

- If r0 is specified by the second operand, the assembler outputs the following message and stops assembling.

E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

4.8.4 Logical instructions

This section describes the logical instructions. Next table lists the instructions described in this section.
See the RH850 product user's manual and architecture edition for details.

Table 4-34. Logical Instructions

Instruction	Meanings
or	Logical sum
ori	Logical sum (immediate)
xor	Exclusive OR
xori	Exclusive OR (immediate)
and	Logical product
andi	Logical product (immediate)
not	Logical negation (takes 1's complement)
shr	Logical right shift
sar	Arithmetic right shift
shl	Logical left shift
sxb	Sign extension of byte data
sxh	Sign extension of 2-byte data
zxb	Zero extension of byte data
zxh	Zero extension of 2-byte data
bsh	Byte swap of half-word data
bsw	Byte swap of word data
hsh	Half-word swap of half-word data
hsw	Half-word swap of word data
tst	Test
sch0l	Bit (0) search from MSB side
sch0r	Bit (0) search from LSB side
sch1l	Bit (1) search from MSB side
sch1r	Bit (1) search from LSB side

or

Logical sum.

[Syntax]

- or reg1, reg2
- or imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "or reg1, reg2"
  ORs the value of the register specified by the first operand with the value of the register specified by the second operand, and stores the result in the register specified by the second operand.
- Syntax "or imm, reg2"
  ORs the value of the absolute expression or relative expression specified by the first operand with the value of the register specified by the second operand, and stores the result in the register specified by the second operand.

[Description]

- When this instruction is executed in syntax "or reg1, reg2", the assembler generates one or machine instruction.
- When this instruction is executed in syntax "or imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions[Note].

(a) 0

`or 0, reg`	`or r0, reg`

(b) Absolute expression having a value in the range of 1 to 65,535

`or imm16, reg`	`ori imm16, reg, reg`

(c) Absolute expression having a value in the range of -16 to -1

`or imm5, reg`	`mov imm5, r1` `or r1, reg`

(d) Absolute expression having a value in the range of -32,768 to -17

`or imm16, reg`	`movea imm16, r0, r1` `or r1, reg`

(e) Absolute expression exceeding the above ranges

If all the lower 16 bits of the value of imm are 0

`or imm, reg`	`movhi HIGHW(imm), r0, r1` `or r1, reg`

Else

`or imm, reg`	`mov imm, r1` `or r1, reg`

(f) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`or $label, reg`	`movea $label, r0, r1` `or r1, reg`

(g) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`or #label, reg`	`mov #label, r1` `or r1, reg`
`or label, reg`	`mov label, r1` `or r1, reg`
`or $label, reg`	`mov $label, r1` `or r1, reg`

Note The or machine instruction does not take an immediate value as an operand.

[Flag]

CY	---
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

ori

Logical sum (immediate).

[Syntax]

- ori imm, reg1, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

[Function]

ORs the value of the absolute expression, relative expression, or expression with HIGHW, LOWW, or HIGHW1 applied specified by the first operand with the value of the register specified by the second operand, and stores the result in the register specified by the third operand.

[Description]

- If the following is specified for imm, the assembler generates one ori machine instruction[Note 1].

(a) Absolute expression having a value in the range of 0 to 65,535

`ori imm16, reg1, reg2`	`ori imm16, reg1, reg2`

(b) Relative expression having !label or %label[Note 2]

`ori !label, reg1, reg2`	`ori !label, reg1, reg2`
`ori %label, reg1, reg2`	`ori %label, reg1, reg2`

(c) Expression with HIGHW, LOWW, or HIGHW1

`ori imm16, reg1, reg2`	`ori imm16, reg1, reg2`

Notes 1. The ori machine instruction takes an immediate value of 0 to 65,535 (0 to 0xFFFF) as the first operand.

2. Values from -32768 to 32767 are specifiable for !label and $label and handled as immediate values (padded with zeros).

- If the following is specified for imm, the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression having a value in the range of -16 to -1

If reg2 is r0

`ori imm5, reg1, r0`	`mov imm5, r1` `or reg1, r1`

Else

ori imm5, reg1, reg2	mov imm5, reg2 or reg1, reg2

(b) Absolute expression having a value in the range of -32,768 to -17

If reg2 is r0

ori imm16, reg1, r0	movea imm16, r0, r1 or reg1, r1

Else

ori imm16, reg1, reg2	movea imm16, r0, reg2 or reg1, reg2

(c) Absolute expression exceeding the above ranges

<1> If all the lower 16 bits of the value of imm are 0

If reg2 is r0

ori imm, reg1, r0	movhi HIGHW(imm), r0, r1 or reg1, r1

Else

ori imm, reg1, reg2	movhi HIGHW(imm), r0, reg2 or reg1, reg2

<2> Else

If reg2 is r0

ori imm, reg1, r0	mov imm, r1 or reg1, r1

Else

ori imm, reg1, reg2	mov imm, reg2 or reg1, reg2

(d) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

If reg2 is r0

`ori $label, reg1, r0`	`movea $label, r0, r1` `or reg1, r1`

Else

`ori $label, reg1, reg2`	`movea $label, r0, reg2` `or reg1, reg2`

(e) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

If reg2 is r0

`ori #label, reg1, r0`	`mov #label, r1` `or reg1, r1`
`ori label, reg1, r0`	`mov label, r1` `or reg1, r1`
`ori $label, reg1, r0`	`mov $label, r1` `or reg1, r1`

Else

`ori #label, reg1, reg2`	`mov #label, reg2` `or reg1, reg2`
`ori label, reg1, reg2`	`mov label, reg2` `or reg1, reg2`
`ori $label, reg1, reg2`	`mov $label, reg2` `or reg1, reg2`

[Flag]

CY	---
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

xor

Exclusive OR.

[Syntax]

- xor reg1, reg2
- xor imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "xor reg1, reg2"
  Exclusive-ORs the value of the register specified by the first operand with the value of the register specified by the second operand, and stores the result in the register specified by the second operand.
- Syntax "xor imm, reg2"
  Exclusive-ORs the value of the absolute expression or relative expression specified by the first operand with the value of the register specified by the second operand, and stores the result in the register specified by the second operan.

[Description]

- When this instruction is executed in syntax "xor reg1, reg2", the assembler generates one xor machine instruction.
- When this instruction is executed in syntax "xor imm, reg2", the assembler executes instruction expansion to generate two or more machine instructions[Note].

(a) 0

`xor 0, reg`	`xor r0, reg`

(b) Absolute expression having a value in the range of 1 to 65,535

`xor imm16, reg`	`xori imm16, reg, reg`

(c) Absolute expression having a value in the range of -16 to -1

`xor imm5, reg`	`mov imm5, r1` `xor r1, reg`

(d) Absolute expression having a value in the range of -32,768 to -17

`xor imm16, reg`	`movea imm16, r0, r1` `xor r1, reg`

(e) Absolute expression exceeding the above ranges

If all the lower 16 bits of the value of imm are 0

`xor imm, reg`	`movhi HIGHW(imm), r0, r1` `xor r1, reg`

Else

`xor imm, reg`	`mov imm, r1` `xor r1, reg`

(f) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`xor $label, reg`	`movea $label, r0, r1` `xor r1, reg`

(g) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`xor #label, reg`	`mov #label, r1` `xor r1, reg`
`xor label, reg`	`mov label, r1` `xor r1, reg`
`xor $label, reg`	`mov $label, r1` `xor r1, reg`

Note The xor machine instruction take an immediate value as an operand.

[Flag]

CY	---
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

xori

Exclusive OR (Immediate).

[Syntax]

- xori imm, reg1, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

[Function]

Exclusive-ORs the value of the absolute expression, relative expression, or expression with HIGHW, LOWW, or HIGHW1 applied specified by the first operand with the value of the register specified by the second operand, and stores the result in the register specified by the third operand.

[Description]

- If the following is specified for imm, the assembler generates one xori machine instruction[Note 1].

(a) Absolute expression having a value in the range of 0 to 65,535

`xori imm16, reg1, reg2`	`xori imm16, reg1, reg2`

(b) Relative expression having !label or %label[Note 2]

`xori !label, reg1, reg2`	`xori !label, reg1, reg2`
`xori %label, reg1, reg2`	`xori %label, reg1, reg2`

(c) Expression with HIGHW, LOWW, or HIGHW1

`xori imm16, reg1, reg2`	`xori imm16, reg1, reg2`

Notes 1. The xori machine instruction takes an immediate value of 0 to 65,535 (0 to 0xFFFF) as the first operand.

2. Values from -32768 to 32767 are specifiable for !label and $label and handled as immediate values (padded with zeros).

- If the following is specified for imm, the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression having a value in the range of -16 to -1

If reg2 is r0

`xori imm5, reg1, r0`	`mov imm5, r1` `xor reg1, r1`

Else

`xori imm5, reg1, reg2`	`mov imm5, reg2` `xor reg1, reg2`

(b) Absolute expression having a value in the range of -32,768 to -17

If reg2 is r0

`xori imm16, reg1, r0`	`movea imm16, r0, r1` `xor reg1, r1`

Else

`xori imm16, reg1, reg2`	`movea imm16, r0, reg2` `xor reg1, reg2`

(c) Absolute expression exceeding the above ranges

<1> If all the lower 16 bits of the value of imm are 0

If reg2 is r0

`xori imm, reg1, r0`	`movhi HIGHW(imm), r0, r1` `xor reg1, r1`

Else

`xori imm, reg1, reg2`	`movhi HIGHW(imm), r0, reg2` `xor reg1, reg2`

<2> Else

If reg2 is r0

`xori imm, reg1, r0`	`mov imm, r1` `xor reg1, r1`

Else

`xori imm, reg1, reg2`	`mov imm, reg2` `xor reg1, reg2`

(d) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

If reg2 is r0

`xori $label, reg1, r0`	`movea $label, r0, r1` `xor reg1, r1`

Else

`xori $label, reg1, reg2`	`movea $label, r0, reg2` `xor reg1, reg2`

(e) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

If reg2 is r0

`xori #label, reg1, r0`	`mov #label, r1` `xor reg1, r1`
`xori label, reg1, r0`	`mov label, r1` `xor reg1, r1`
`xori $label, reg1, r0`	`mov $label, r1` `xor reg1, r1`

Else

`xori #label, reg1, reg2`	`mov #label, reg2` `xor reg1, reg2`
`xori label, reg1, reg2`	`mov label, reg2` `xor reg1, reg2`
`xori $label, reg1, reg2`	`mov $label, reg2` `xor reg1, reg2`

[Flag]

CY	---
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

and

Logical product.

[Syntax]

- and reg1, reg2
- and imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "and reg1, reg2"
  ANDs the value of the register specified by the first operand with the value of the register specified by the second operand, and stores the result in the register specified by the second operand.
- Syntax "and imm, reg2"
  ANDs the value of the absolute expression or relative expression specified by the first operand with the value of the register specified by the second operand, and stores the result in the register specified by the second operand.

[Description]

- When this instruction is executed in syntax "and reg1, reg2", the assembler generates one and machine instruction.
- When this instruction is executed in syntax "and imm, reg2", the assembler executes instruction expansion to generate one or more machine instruction[Note].

(a) 0

`and 0, reg`	`and r0, reg`

(b) Absolute expression having a value in the range of 1 to 65,535

`and imm16, reg`	`andi imm16, reg, reg`

(c) Absolute expression having a value in the range of -16 to -1

`and imm5, reg`	`mov imm5, r1` `and r1, reg`

(d) Absolute expression having a value in the range of -32,768 to -17

`and imm16, reg`	`movea imm16, r0, r1` `and r1, reg`

(e) Absolute expression exceeding the above ranges

If all the lower 16 bits of the value of imm are 0

`and imm, reg`	`movhi HIGHW(imm), r0, r1` `and r1, reg`

Else

`and imm, reg`	`mov imm, r1` `and r1, reg`

(f) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`and $label, reg`	`movea $label, r0, r1` `and r1, reg`

(g) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`and #label, reg`	`mov #label, r1` `and r1, reg`
`and label, reg`	`mov label, r1` `and r1, reg`
`and $label, reg`	`mov $label, r1` `and r1, reg`

Note The and machine instruction does not take an immediate value as an operand.

[Flag]

CY	---
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

andi

Logical product (immediate).

[Syntax]

- andi imm, reg1, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

[Function]

ANDs the value of the absolute expression, relative expression, or expression with HIGHW, LOWW, or HIGHW1 applied specified by the first operand with the value of the register specified by the second operand, and stores the result into the register specified by the third operand.

[Description]

- If the following is specified as imm, the assembler generates one andi machine instruction[Note 1].

(a) Absolute expression having a value in the range of 0 to 65,535

`andi imm16, reg1, reg2`	`andi imm16, reg1, reg2`

(b) Relative expression having !label or %label[Note 2]

`andi !label, reg1, reg2`	`andi !label, reg1, reg2`
`andi %label, reg1, reg2`	`andi %label, reg1, reg2`

(c) Expression with HIGHW, LOWW, or HIGHW1

`andi imm16, reg1, reg2`	`andi imm16, reg1, reg2`

Notes 1. The andi machine instruction takes an immediate value of 0 to 65,535 (0 to 0xFFFF) as the first operand.

2. Values from -32768 to 32767 are specifiable for !label and $label and handled as immediate values (padded with zeros).

- If the following is specified for imm, the assembler executes instruction expansion to generate one or more machine instructions.

(a) Absolute expression having a value in the range of -16 to -1

If reg2 is r0

`andi imm5, reg1, r0`	`mov imm5, r1` `and reg1, r1`

Else

`andi imm5, reg1, reg2`	`mov imm5, reg2` `and reg1, reg2`

(b) Absolute expression having a value in the range of -32,768 to -17

If reg2 is r0

`andi imm16, reg1, r0`	`movea imm16, r0, r1` `and reg1, r1`

Else

`andi imm16, reg1, reg2`	`movea imm16, r0, reg2` `and reg1, reg2`

(c) Absolute expression exceeding the above ranges

<1> If all the lower 16 bits of the value of imm are 0

If reg2 is r0

`andi imm, reg1, r0`	`movhi HIGHW(imm), r0, r1` `and reg1, r1`

Else

`andi imm, reg1, reg2`	`movhi HIGHW(imm), r0, reg2` `and reg1, reg2`

<2> Else

If reg2 is r0

`andi imm, reg1, r0`	`mov imm, r1` `and reg1, r1`

Else

`andi imm, reg1, reg2`	`mov imm, reg2` `and reg1, reg2`

(d) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

If reg2 is r0

`andi $label, reg1, r0`	`movea $label, r0, r1` `and reg1, r1`

Else

`andi $label, reg1, reg2`	`movea $label, r0, reg2` `and reg1, reg2`

(e) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

If reg2 is r0

`andi #label, reg1, r0`	`mov #label, r1` `and reg1, r1`
`andi label, reg1, r0`	`mov label, r1` `and reg1, r1`
`andi $label, reg1, r0`	`mov $label, r1` `and reg1, r1`

Else

`andi #label, reg1, reg2`	`mov #label, reg2` `and reg1, reg2`
`andi label, reg1, reg2`	`mov label, reg2` `and reg1, reg2`
`andi $label, reg1, reg2`	`mov $label, reg2` `and reg1, reg2`

[Flag]

CY	---
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

not

Logical negation (takes 1's complement).

[Syntax]

- not reg1, reg2
- not imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "not reg1, reg2"
  NOTs (1's complement) the value of the register specified by the first operand, and stores the result in the register specified by the second operand.
- Syntax "not imm, reg2"
  NOTs (1's complement) the value of the absolute expression or relative expression specified by the first operand, and stores the result in the register specified by the second operand.

[Description]

- When this instruction is executed in syntax "not reg1, reg2", the assembler generates one not machine instruction.
- When this instruction is executed in syntax "not imm, reg2", the assembler executes instruction expansion to generate one or more machine instructions[Note].

(a) 0

`not 0, reg`	`not r0, reg`

(b) Absolute expression having a value of other than 0 within the range of -16 to +15

`not imm5, reg`	`mov imm5, r1` `not r1, reg`

(c) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`not imm16, reg`	`movea imm16, r0, r1` `not r1, reg`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`not imm, reg`	`movhi HIGHW(imm), r0, r1` `not r1, reg`

Else

`not imm, reg`	`mov imm, r1` `not r1, reg`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`not $label, reg`	`movea $label, r0, r1` `not r1, reg`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`not #label, reg`	`mov #label, r1` `not r1, reg`
`not label, reg`	`mov label, r1` `not r1, reg`
`not $label, reg`	`mov $label, r1` `not r1, reg`

Note The not machine instruction does not take an immediate value as an operand.

[Flag]

CY	---
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

shr

Logical right shift.

[Syntax]

- shr reg1, reg2
- shr imm5, reg2
- shr reg1, reg2, reg3

The following can be specified for imm5:

- Absolute expression having a value of up to 5 bits

[Function]

- Syntax "shr reg1, reg2"
  Logically shifts to the right the value of the register specified by the second operand by the number of bits indicated by the lower 5 bits of the register value specified by the first operand, then stores the result in the register specified by the second operand.
- Syntax "shr imm5, reg2"
  Logically shifts to the right the value of the register specified by the second operand by the number of bits specified by the value of the absolute expression specified by the first operand, then stores the result in the register specified by the second operand.
- Syntax "shr reg1, reg2, reg3"
  Logically shifts to the right the value of the register specified by the second operand by the number of bits indicated by the lower 5 bits of the register value specified by the first operand, then stores the result in the register specified by the third operand.

[Description]

The assembler generates one shr machine instruction.

[Flag]

CY	1 if the value of the bit shifted out last is 1, 0 if not (0 if the specified number of bits is 0)
OV	0
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of 0 to 31 is specified as imm5 in syntax "shr imm5, reg2", the assembler outputs the following message, and continues assembling by using the lower 5 bits[Note] of the specified value.

```
W0550011 : illegal operand (range error in immediate).
```

Note The shr machine instruction takes an immediate value of 0 to 31 (0x0 to 0x1F) as the first operand.

sar

Arithmetic right shift.

[Syntax]

- sar reg1, reg2
- sar imm5, reg2
- sar reg1, reg2, reg3

The following can be specified for imm5:

- Absolute expression having a value of up to 5 bits

[Function]

- Syntax "sar reg1, reg2"
  Arithmetically shifts to the right the value of the register specified by the second operand by the number of bits indicated by the lower 5 bits of the register value specified by the first operand, then stores the result in the register specified by the second operand.
- Syntax "sar imm5, reg2"
  Arithmetically shifts to the right the value of the register specified by the second operand by the number of bits specified by the value of the absolute expression specified by the first operand, then stores the result in the register specified by the second operand.
- Syntax "sar reg1, reg2, reg3"
  Arithmetically shifts to the right the value of the register specified by the second operand by the number of bits indicated by the lower 5 bits of the register value specified by the first operand, then stores the result in the register specified by the third operand.

[Description]

The assembler generates one sar machine instruction.

[Flag]

CY	1 if the value of the bit shifted out last is 1, 0 if not (0 if the specified number of bits is 0)
OV	0
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of 0 to 31 is specified for imm5 in syntax "sar imm5, reg2", the assembler outputs the following message, and continues assembling using the lower 5 bits[Note] of the specified value.

```
W0550011 : illegal operand (range error in immediate).
```

Note The sar machine instruction takes an immediate value of 0 to 31 (0x0 to 0x1F) as the first operand.

shl

Logical left shift.

[Syntax]

- shl reg1, reg2
- shl imm5, reg2
- shl reg1, reg2, reg3

The following can be specified for imm5:

- Absolute expression having a value of up to 5 bits

[Function]

- Syntax "shl reg1, reg2"
  Logically shifts to the left the value of the register specified by the second operand by the number of bits indicated by the lower 5 bits of the register value specified by the first operand, then stores the result in the register specified by the second operand.
- Syntax "shl imm5, reg2"
  Logically shifts to the left the value of the register specified by the second operand by the number of bits specified by the value of the absolute expression specified by the first operand, then stores the result in the register specified by the second operand.
- Syntax "shl reg1, reg2, reg3"
  Logically shifts to the left the value of the register specified by the second operand by the number of bits indicated by the lower 5 bits of the register value specified by the first operand, then stores the result in the register specified by the third operand.

[Description]

The assembler generates one shl machine instruction.

[Flag]

CY	1 if the value of the bit shifted out last is 1, 0 if not (0 if the specified number of bits is 0)
OV	0
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of 0 to 31 is specified for imm5 in syntax "shl imm5, reg2", the assembler outputs the following message, and continues assembling by using the lower 5 bits[Note] of the specified value.

```
W0550011 : illegal operand (range error in immediate).
```

Note The shl machine instruction takes an immediate value of 0 to 31 (0x0 to 0x1F) as the first operand.

sxb

Sign extension of byte data.

[Syntax]

- sxb reg

[Function]

Sign-extends the data of the lowermost byte of the register specified by the first operand to word length.

[Description]

The assembler generates one sxb machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

sxh

Sign extension of 2-byte data.

[Syntax]

- sxh reg

[Function]

Sign-extends the data of the lower 2 bytes of the register specified by the first operand to word length.

[Description]

The assembler generates one sxh machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

zxb

Zero extension of byte data.

[Syntax]

- zxb reg

[Function]

Zero-extends the data of the lowermost byte of the register specified by the first operand to word length.

[Description]

The assembler generates one zxb machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

zxh

Zero extension of 2-byte data

[Syntax]

- zxh reg

[Function]

Zero-extends the data of the lower 2 bytes of the register specified by the first operand to word length.

[Description]

The assembler generates one zxh machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

bsh

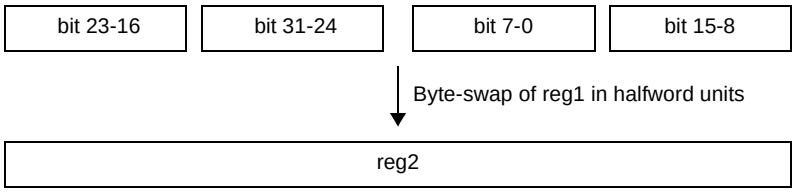
Byte swap of half-word data.

[Syntax]

- bsh reg1, reg2

[Function]

Byte-swaps the register value specified by the first operand in halfword units and stores the result in the register specified by the second operand.



[Description]

The assembler generates one bsh machine instruction.

[Flag]

CY	1 if either or both of the bytes in the lower halfword of the register is 0, 0 if not
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the lower half-word data of the result is 0, 0 if not
SAT	---

bsw

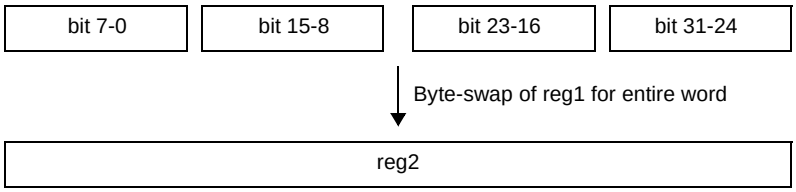
Byte swap of word data.

[Syntax]

- bsw reg1, reg2

[Function]

Byte-swaps the register value specified by the first operand and stores the result in the register specified by the second operand.



[Description]

The assembler generates one bsw machine instruction.

[Flag]

CY	1 if one or more bytes of the word in the register is 0, 0 if not
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the word data of the result is 1, 0 if not
SAT	---

hsh

Half-word swap of half-word data.

[Syntax]

- hsh reg1, reg2

[Function]

Stores the register value specified by the first operand in the register specified by the second operand, and stores the flag assessment result in the PSW register.

[Description]

The assembler generates one hsh machine instruction.

[Flag]

CY	1 if the lower half-word data of the result is 0, 0 if not
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the lower half-word data of the result is 0, 0 if not
SAT	---

hsw

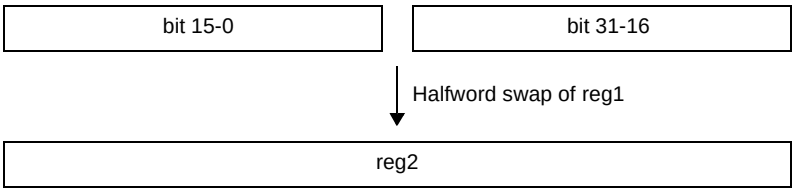
Half-word swap of word data.

[Syntax]

- hsw reg1, reg2

[Function]

Halfword-swaps the register value specified by the first operand and stores the result in the register specified by the second operand.



[Description]

The assembler generates one hsw machine instruction.

[Flag]

CY	1 if one or more halfwords in the word of the register is 0, 0 if not
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the word data of the result is 1, 0 if not
SAT	---

tst

Test.

[Syntax]

- tst reg1, reg2
- tst imm, reg2

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits
- Relative expression

[Function]

- Syntax "tst reg1, reg2"
  ANDs the value of the register specified by the second operand with the value of the register specified by the first operand, and sets only the flags without storing the result.
- Syntax "tst imm, reg2"
  ANDs the value of the register specified by the second operand with the value of the absolute expression or relative expression specified by the first operand, and sets only the flags without storing the result.

[Description]

- When this instruction is executed in syntax "tst reg1, reg2", the assembler generates one tst machine instruction.
- When this instruction is executed in syntax "tst imm, reg2", the assembler executes instruction expansion to generate two or more machine instructions[Note].

(a) 0

`tst 0, reg`	`tst r0, reg`

(b) Absolute expression having a value of other than 0 within the range of -16 to +15

`tst imm5, reg`	`mov imm5, r1` `tst r1, reg`

(c) Absolute expression exceeding the range of -16 to +15, but within the range of -32,768 to +32,767

`tst imm16, reg`	`movea imm16, r0, r1` `tst r1, reg`

(d) Absolute expression having a value exceeding the range of -32,768 to +32,767

If all the lower 16 bits of the value of imm are 0

`tst imm, reg`	`movhi HIGHW(imm), r0, r1` `tst r1, reg`

Else

`tst imm, reg`	`mov imm, r1` `tst r1, reg`

(e) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`tst $label, reg`	`movea $label, r0, r1` `tst r1, reg`

(f) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`tst #label, reg`	`mov #label, r1` `tst r1, reg`
`tst label, reg`	`mov label, r1` `tst r1, reg`
`tst $label, reg`	`mov $label, r1` `tst r1, reg`

Note The tst machine instruction take an immediate value as an operand.

[Flag]

CY	---
OV	0
S	1 if the word data MSB of the result is 1, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

sch0l

Bit (0) search from MSB side (search zero from left).

[Syntax]

- sch0l reg1, reg2

[Function]

Searches the word data of the register specified by the first operand, from the left (MSB side), and stores the position of the first bit (0) found in the register specified by the second operand in hexadecimal. (For example, if bit 31 of the register specified by the first operand is 0, 01H is stored in the register specified by the second operand.)

If no bit (0) is found, 0 is written into the register specified by the second operand, and the Z flag is simultaneously set (1). If a bit (0) is found at the end, the CY flag is set (1).

[Description]

The assembler generates one sch0l machine instruction.

[Flag]

CY	1 if a bit (0) is found at the end, 0 if not
OV	0
S	0
Z	1 if a bit (0) is not found, 0 if not
SAT	---

sch0r

Bit (0) search from LSB side (search zero from right).

[Syntax]

- sch0r reg1, reg2

[Function]

Searches the word data of the register specified by the first operand, from the right (LSB side), and stores the position of the first bit (0) found in the register specified by the second operand in hexadecimal. (For example, if bit 0 of the register specified by the first operand is 0, 01H is stored in the register specified by the second operand.)

If no bit (0) is found, 0 is written into the register specified by the second operand, and the Z flag is simultaneously set (1). If a bit (0) is found at the end, the CY flag is set (1).

[Description]

The assembler generates one sch0r machine instruction.

[Flag]

CY	1 if a bit (0) is found at the end, 0 if not
OV	0
S	0
Z	1 if a bit (0) is not found, 0 if not
SAT	---

sch1l

Bit (1) search from MSB side (search one from left).

[Syntax]

- sch1l reg1, reg2

[Function]

Searches the word data of the register specified by the first operand, from the left (MSB side), and stores the position of the first bit (1) found in the register specified by the second operand in hexadecimal. (For example, if bit 31 of the register specified by the first operand is 1, 01H is stored in the register specified by the second operand.)

If no bit (1) is found, 0 is written into the register specified by the second operand, and the Z flag is simultaneously set (1). If a bit (0) is found at the end, the CY flag is set (1).

[Description]

The assembler generates one sch1l machine instruction.

[Flag]

CY	1 if a bit (1) is found at the end, 0 if not
OV	0
S	0
Z	1 if a bit (1) is not found, 0 if not
SAT	---

sch1r

Bit (1) search from LSB side (search zero from right).

[Syntax]

- sch1r reg1, reg2

[Function]

Searches the word data of the register specified by the first operand, from the right (LSB side), and stores the position of the first bit (1) found in the register specified by the second operand in hexadecimal. (For example, if bit 0 of the register specified by the first operand is 1, 01H is stored in the register specified by the second operand.)

If no bit (1) is found, 0 is written into the register specified by the second operand, and the Z flag is simultaneously set (1). If a bit (1) is found at the end, the CY flag is set (1).

[Description]

The assembler generates one sch1r machine instruction.

[Flag]

CY	1 if a bit (1) is found at the end, 0 if not
OV	0
S	0
Z	1 if a bit (1) is not found, 0 if not
SAT	---

4.8.5 Branch instructions

This section describes the branch instructions. Next table lists the instructions described in this section.
See the RH850 product user's manual and architecture edition for details.

Table 4-35. Branch Instructions

Instruction	Meanings
jmp	Unconditional branch
jmp32	Unconditional branch
jr	Unconditional branch (PC relative)
jr22	Unconditional branch (PC relative)
jr32	Unconditional branch (PC relative)
jcnd	Conditional branch
jcnd9	Conditional branch
jcnd17	Conditional branch
jarl	Jump and register link
jarl22	Jump and register link
jarl32	Jump and register link

jmp

Unconditional branch.

[Syntax]

- jmp [reg]
- jmp addr
- jmp disp32[reg]

The following can be specified for addr:

- Relative expression having the absolute address reference of a label

The following can be specified for disp32:

- Absolute expression having a value of up to 32 bits
- Relative expression with a reference to the absolute address of a label and a reference to the offset within a section

[Function]

- Syntax "jmp [reg]"
  Transfers control to the address indicated by the value of the register specified by the operand.
- Syntax "jmp disp32[reg]"
  Transfers control to the address attained by adding the displacement specified by the operand and the register content.
- Syntax "jmp addr"
  Transfers control to the address indicated by the value of the relative expression specified by the operand.

[Description]

- When this instruction is executed in syntax "jmp [reg]", the assembler generates one jmp machine instruction.
- If the instruction is executed in syntax "jmp addr", when the RH850 operate, the assembler generates one jmp machine instruction (6-byte long instruction).
- When this instruction is executed in syntax "jmp disp32[reg]", the assembler generates one jmp (6-byte long instruction) machine instructions.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an expression other than a relative expression having the absolute address reference of a label is specified as addr in syntax "jmp addr", the assembler outputs the following message and stops assembling.

```
E0550224 : Illegal operand (label reference for jmp must be string).
```

jmp32

Unconditional branch.

[Syntax]

- jmp32 disp32[reg]
- jmp32 addr

The following can be specified for addr:

- Relative expression having the absolute address reference of a label

The following can be specified for disp32:

- Absolute expression having a value of up to 32 bits
- Relative expression with a reference to the absolute address of a label and a reference to the offset within a section

[Function]

- Syntax "jmp32 disp32[reg]"
  Transfers control to the address attained by adding the displacement specified by the operand and the register content.
- Syntax "jmp32 addr"
  Transfers control to the address indicated by the value of the relative expression specified by the operand.

[Description]

The assembler generates one jmp machine instruction (6-byte long instruction).

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an expression other than a relative expression having the absolute address reference of a label is specified as addr in syntax "jmp32 addr", the assembler outputs the following message and stops assembling.

```
E0550224 : Illegal operand (label reference for jmp must be string).
```

jr

Unconditional branch (PC relative).

[Syntax]

- jr disp22
- jr disp32

The following can be specified for disp22:
- Absolute expression having a value of up to 22 bits
- Relative expression having a PC offset reference of label

The following can be specified for disp32:
- Absolute expression having a value of up to 32 bits
- Relative expression having a PC offset reference of label

[Function]

- Syntax "jr disp22"
  Transfers control to the address attained by adding the current program counter (PC) value and the relative or absolute expression value specified by the first operand.
- Syntax "jr disp32"
  Transfers control to the address attained by adding the current program counter (PC) value and the relative or absolute expression value specified by the first operand.

[Description]

- If the instruction is executed in syntax "jr disp22", the assembler generates one jr machine instruction[Note] if any of the following expressions are specified for disp22.

  (a) Absolute expression having a value in the range of -2,097,152 to +2,097,151

  (b) Relative expression that has a PC offset reference of label having a definition in the same section of the same file as this instruction, and having a value in the range of -2,097,152 to +2,097,151

  (c) Relative expression having a PC offset reference of a label with no definition in the same file or section as this instruction

  Note The jr machine instruction takes an immediate value in the range of -2,097,152 to +2,097,151 (0xFE00000 to 0x1FFFFF) as the displacement.

- If the instruction is executed in syntax "jr disp32", the assembler generates one jr machine instruction (6-byte long instruction).

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of -2,097,152 to +2,097,151, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction, and having a value exceeding the range of -2,097,152 to +2,097,151, is specified as disp22, the assembler outputs the following message and stops assembling.

```
E0550230 : illegal operand (range error in displacement)
```

- If an absolute expression having an odd-numbered value or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction, and having an odd-numbered value, is specified as disp22/disp32, the assembler outputs the following message and stops assembling.

```
E0550226 : illegal operand (must be even displacement)
```

- When the -Xfar_jump assembler option is not specified, and an absolute expression outside of the range -2,097,152 to +2,097,151 or a relative expression outside of the range -2,097,152 to +2,097,151, having a label PC offset reference with a definition in the same file and same section as this instruction, is specified as disp32, the following message is output and assembly is stopped.

```
E0550230 : illegal operand (range error in displacement)
```

jr22

Unconditional branch (PC relative).

[Syntax]

- jr22 disp22

The following can be specified for disp22:

- Absolute expression having a value of up to 22 bits
- Relative expression having a PC offset reference of label

[Function]

Transfers control to the address attained by adding the current program counter (PC) value and the relative or absolute expression value specified by the operand.

[Description]

- If the following is specified for disp22, the assembler generates one jr machine instruction[Note].

(a) Absolute value in the range of -2,097,152 to +2,097,151

(b) Relative expression that has a PC offset reference of label having a definition in the same section and the same file as this instruction, and which has a value in the range of -2,097,152 to +2,097,151

(c) Relative expression having a PC offset reference of a label having no definition in the same file or section as this instruction

Note The jr machine instruction takes an immediate value in the range of -2,097,152 to +2,097,151 (0xFE00000 to 0x1FFFFF) as the displacement.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression that exceeds the range of -2,097,152 to +2,097,151, or a relative expression having a PC offset reference of label with a definition in the same section and the same file as this instruction and having a value that falls outside the range of -2,097,152 to +2,097,151 is specified as disp22, the assembler outputs the following message and stops assembling.

```
E0550230 : illegal operand (range error in displacement)
```

- If an absolute expression having an odd-numbered value, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction and having an odd-numbered value, is specified as disp22, the assembler outputs the following message and stops assembling.

E0550226 : illegal operand (must be even displacement)

jr32

Unconditional branch (PC relative).

[Syntax]

- jr32 disp32

The following can be specified for disp32:

- Absolute expression having a value of up to 32 bits
- Relative expression having a PC offset reference of label

[Function]

Transfers control to the address attained by adding the current program counter (PC) value and the relative or absolute expression value specified by the first operand.

[Description]

The assembler generates one jr machine instruction (6-byte long instruction).

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having an odd-numbered value, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction and having an odd-numbered value, is specified as disp32, the assembler outputs the following message and stops assembling.

```
E0550226: illegal operand (must be even displacement)
```

jcnd

Conditional branch.

[Syntax]

- *jcnd* disp22

The following can be specified for disp22:

- Absolute expression having a value of up to 22 bits
- Relative expression having a PC offset reference of label

[Function]

Compares the flag condition indicated by string *cnd* (see "Table 4-36. jcnd Instruction List") with the current flag condition. If they are found to be the same, transfers control to the address obtained by adding the value of the absolute expression or relative expression specified by the operand to the current value of the program counter (PC)[Note].

Note For a *jcnd* instruction other than jbr, the mnemonic "b*cnd*" can be used, and the "br" machine-language instruction can be used for the jbr instruction (there is no functional difference).

Table 4-36. *jcnd* Instruction List

Instruction	Flag Condition	Meaning of Flag Condition
jgt	((S xor OV) or Z) = 0	Greater than (signed)
jge	(S xor OV) = 0	Greater than or equal (signed)
jlt	(S xor OV) = 1	Less than (signed)
jle	((S xor OV) or Z) = 1	Less than or equal (signed)
jh	(CY or Z) = 0	Higher (Greater than)
jnl	CY = 0	Not lower (Greater than or equal)
jl	CY = 1	Lower (Less than)
jnh	(CY or Z) = 1	Not higher (Less than or equal)
je	Z = 1	Equal
jne	Z = 0	Not equal
jv	OV = 1	Overflow
jnv	OV = 0	No overflow
jn	S = 1	Negative
jp	S = 0	Positive
jc	CY = 1	Carry
jnc	CY = 0	No carry
jz	Z = 1	Zero
jnz	Z = 0	Not zero
jbr	---	Always (Unconditional)
jsa	SAT = 1	Saturated

[Description]

- If the following is specified for disp22, the assembler generates one bcond machine instruction[Note].

(a) Absolute expression having a value in the range of -256 to +255

(b) Absolute expression having a PC offset reference for a label with a definition in the same section and the same file as this instruction and having a value in the range of -256 to +255

j*cnd* disp9	b*cnd* disp9

Note The b*cnd* machine instruction takes an immediate value in the range of -256 to +255 (0xFFFFFF00 to 0xFF) as the displacement.

- If the following is specified as disp22, the assembler executes instruction expansion and generates two or more machine instructions.

(a) Absolute expression having a value exceeding the range of -256 to +255 but within the range of -2,097,150 to +2,097,153[Note 1]

(b) Relative expression having a PC offset reference of label with a definition in the same section of the same file as this instruction and having a value exceeding the range of -256 to +255 but within the range of -2,097,150 to +2,097,153

(c) Relative expression having a PC offset reference of label without a definition in the same file or section as this instruction

jbr disp22	jr disp22
jsa disp22	bsa Label1 br Label2 Label1: jr disp22 - 4 Label2:
j*cnd* disp22	bn*cnd* Label[Note 2] jr disp22 - 2 Label:

Notes 1. The range of -2,097,150 to +2,097,153 applies to instructions other than jbr and jsa. The range for the jbr instruction is from -2,097,152 to +2,097,151, and that for the jsa instruction is from -2,097,148 to +2,097,155.

2. bn*cnd* denotes an instruction that effects control branches under opposite conditions, for example, bnz for bz or ble for bgt.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of -2,097,150 to +2,097,153, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction, and having a value exceeding the range of -2,097,150 to +2,097,153, is specified as disp22, the assembler outputs the following message and stops assembling.

```
E0550230 : illegal operand (range error in displacement)
```

- If an absolute expression having an odd-numbered value, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction, and having an odd-numbered value, is specified as disp22, the assembler outputs the following message and stops assembling.

```
E0550226 : illegal operand (must be even displacement)
```

- If you wish to use a j*cnd* instruction with 17-bit absolute expression as disp22, use the j*cnd*17 instruction instead.

j*cnd*9

Conditional branch.

[Syntax]

- j*cnd*9 disp9

The following can be specified for disp9:

- Absolute expression having a value of up to 17 bits
- Relative expression having a PC offset reference of label

[Function]

Compares the flag condition indicated by string *cnd* (see "Table 4-37. jcnd9 Instruction List") with the current flag condition. If they are found to be the same, transfers control to the address obtained by adding the value of the absolute expression or relative expression specified by the operand to the current value of the program counter (PC)[Note].

Note For a j*cnd* instruction other than jbr, the mnemonic "b*cnd*" can be used, and the "br" machine-language instruction can be used for the jbr instruction (there is no functional difference).

Table 4-37. j*cnd*9 Instruction List

Instruction	Flag Condition	Meaning of Flag Condition
jgt	((S xor OV) or Z) = 0	Greater than (signed)
jge	(S xor OV) = 0	Greater than or equal (signed)
jlt	(S xor OV) = 1	Less than (signed)
jle	((S xor OV) or Z) = 1	Less than or equal (signed)
jh	(CY or Z) = 0	Higher (Greater than)
jnl	CY = 0	Not lower (Greater than or equal)
jl	CY = 1	Lower (Less than)
jnh	(CY or Z) = 1	Not higher (Less than or equal)
je	Z = 1	Equal
jne	Z = 0	Not equal
jv	OV = 1	Overflow
jnv	OV = 0	No overflow
jn	S = 1	Negative
jp	S = 0	Positive
jc	CY = 1	Carry
jnc	CY = 0	No carry
jz	Z = 1	Zero
jnz	Z = 0	Not zero
jbr	---	Always (Unconditional)
jsa	SAT = 1	Saturated

[Description]

- If the following is specified for disp9, the assembler generates one bcond machine instruction.

(a) Absolute expression having a value in the range of -256 to +255

(b) Absolute expression having a PC offset reference for a label with a definition in the same section and the same file as this instruction and having a value in the range of -256 to +255

jcnd disp9	b*cnd* disp9

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of -256 to +255, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction, and having a value exceeding the range of -256 to +255, is specified as disp9, the assembler outputs the following message and stops assembling.

```
E0550230 : illegal operand (range error in displacement)
```

- If an absolute expression having an odd-numbered value, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction, and having an odd-numbered value, is specified as disp9, the assembler outputs the following message and stops assembling.

```
E0550226 : illegal operand (must be even displacement)
```

j*cnd*17

Conditional branch.

[Syntax]

- j*cnd*17 disp17

The following can be specified for disp17:

- Absolute expression having a value of up to 9 bits
- Relative expression having a PC offset reference of label

[Function]

Compares the flag condition indicated by string *cnd* (see "Table 4-38. jcnd17 Instruction List") with the current flag condition. If they are found to be the same, transfers control to the address obtained by adding the value of the absolute expression or relative expression specified by the operand to the current value of the program counter (PC)[Note].

Note For a j*cnd* instruction other than jbr, the mnemonic "b*cnd*" can be used, and the "br" machine-language instruction can be used for the jbr instruction (there is no functional difference).

Table 4-38. j*cnd*17 Instruction List

Instruction	Flag Condition	Meaning of Flag Condition
jgt	((S xor OV) or Z) = 0	Greater than (signed)
jge	(S xor OV) = 0	Greater than or equal (signed)
jlt	(S xor OV) = 1	Less than (signed)
jle	((S xor OV) or Z) = 1	Less than or equal (signed)
jh	(CY or Z) = 0	Higher (Greater than)
jnl	CY = 0	Not lower (Greater than or equal)
jl	CY = 1	Lower (Less than)
jnh	(CY or Z) = 1	Not higher (Less than or equal)
je	Z = 1	Equal
jne	Z = 0	Not equal
jv	OV = 1	Overflow
jnv	OV = 0	No overflow
jn	S = 1	Negative
jp	S = 0	Positive
jc	CY = 1	Carry
jnc	CY = 0	No carry
jz	Z = 1	Zero
jnz	Z = 0	Not zero
jbr	---	Always (Unconditional)
jsa	SAT = 1	Saturated

[Description]

- If the following is specified for disp17, the assembler generates one bcond machine instruction.

(a) Absolute expression having a value in the range of -65,536 to +65,535

(b) Absolute expression having a PC offset reference for a label with a definition in the same section and the same file as this instruction and having a value in the range of -65,536 to +65,535

jcnd disp17	b*cnd* disp17

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of -65,536 to +65,536, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction, and having a value exceeding the range of -65,536 to +65,535, is specified as disp17, the assembler outputs the following message and stops assembling.

```
E0550230 : illegal operand (range error in displacement)
```

- If an absolute expression having an odd-numbered value, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction, and having an odd-numbered value, is specified as disp17, the assembler outputs the following message and stops assembling.

```
E0550226 : illegal operand (must be even displacement)
```

jarl

Jump and register link.

[Syntax]

- jarl disp22, reg2
- jarl disp32, reg2
- jarl [reg1], reg3

The following can be specified for disp22:
- Absolute expression having a value of up to 22 bits
- Relative expression having a PC offset reference of label

The following can be specified for disp32:
- Absolute expression having a value of up to 32 bits
- Relative expression having a PC offset reference of label

[Function]

- Syntax "jarl disp22, reg2"
  Transfers control to the address attained by adding the current program counter (PC) value and the relative or absolute expression value specified by the first operand. The return address is stored in the register specified by the second operand.
- Syntax "jarl disp32, reg2"
  Transfers control to the address attained by adding the current program counter (PC) value and the relative or absolute expression value specified by the first operand. The return address is stored in the register specified by the second operand.
- Syntax "jarl [reg1], reg3"
  This moves control to the address indicated by the register value specified in the first operand, plus the value of the current program counter (PC). The return address is stored in the register specified in the second operand.

[Description]

- If the instruction is executed in syntax "jarl disp22, reg2", the assembler generates one jarl machine instruction[Note] if any of the following expressions are specified for disp22.

  (a) Absolute value in the range of -2,097,152 to +2,097,151

  (b) Relative expression that has a PC offset reference of label having a definition in the same section and the same file as this instruction, and which has a value in the range of -2,097,152 to +2,097,151

  (c) Relative expression having a PC offset reference of a label having no definition in the same file or section as this instruction

  Note The jarl machine instruction takes an immediate value in the range of -2,097,152 to +2,097,151 (0xFE00000 to 0x1FFFFF) as the operand.

- If the instruction is executed in syntax "jarl disp32, reg2", the assembler generates one jarl machine instruction (6-byte long instruction).
- If the instruction is executed in syntax "jarl [reg1], reg3", the assembler generates one jarl machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression that exceeds the range of -2,097,152 to +2,097,151, or a relative expression having a PC offset reference of label with a definition in the same section and the same file as this instruction and having a value that falls outside the range of -2,097,152 to +2,097,151 is specified as disp22, the assembler outputs the following message and stops assembling.

```
E0550230 : illegal operand (range error in displacement)
```

- If an absolute expression having an odd-numbered value, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction and having an odd-numbered value, is specified as disp22/disp32, the assembler outputs the following message and stops assembling.

```
E0550226 : illegal operand (must be even displacement)
```

- When the -Xfar_jump assembler option is not specified, and an absolute expression outside of the range -2,097,152 to +2,097,151 or a relative expression outside of the range -2,097,152 to +2,097,151, having a label PC offset reference with a definition in the same file and same section as this instruction, is specified as disp32, the following message is output and assembly is stopped.

```
E0550230 : illegal operand (range error in displacement)
```

- If r0 is specified as reg3, the assembler outputs the following message and stops assembling.

```
E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).
```

jarl22

Jump and register link.

[Syntax]

- jarl22 disp22, reg1

The following can be specified for disp22:

- Absolute expression having a value of up to 22 bits
- Relative expression having a PC offset reference of label

[Function]

Transfers control to the address attained by adding the current program counter (PC) value and the relative or absolute expression value specified by the first operand. The return address is stored in the register specified by the second operand.

[Description]

- If the following is specified for disp22, the assembler generates one jarl machine instruction[Note].

(a) Absolute value in the range of -2,097,152 to +2,097,15

(b) Relative expression that has a PC offset reference of label having a definition in the same section and the same file as this instruction, and which has a value in the range of -2,097,152 to +2,097,151

(c) Relative expression having a PC offset reference of a label having no definition in the same file or section as this instruction

Note The jarl machine instruction takes an immediate value in the range of -2,097,152 to +2,097,151 (0xFE00000 to 0x1FFFFF) as the operand.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression that exceeds the range of -2,097,152 to +2,097,151, or a relative expression having a PC offset reference of label with a definition in the same section and the same file as this instruction and having a value that falls outside the range of -2,097,152 to +2,097,151 is specified as disp22, the assembler outputs the following message and stops assembling.

```
E0550230 : illegal operand (range error in displacement)
```

- If an absolute expression having an odd-numbered value, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction and having an odd-numbered value, is specified as disp22, the assembler outputs the following message and stops assembling.

E0550226 : illegal operand (must be even displacement)

jarl32

Jump and register link.

[Syntax]

- jarl32 disp32, reg2

The following can be specified for disp32:

- Absolute expression having a value of up to 32 bits
- Relative expression having a PC offset reference of label

[Function]

Transfers control to the address attained by adding the current program counter (PC) value and the relative or absolute expression value specified by the first operand. The return address is stored in the register specified by the second operand.

[Description]

The assembler generates one jarl machine instruction (6-byte long instruction).

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having an odd-numbered value, or a relative expression having a PC offset reference of a label with a definition in the same section and the same file as this instruction, and having an odd-numbered value, is specified as disp32, the assembler outputs the following message and stops assembling.

```
E0550226 : illegal operand (must be even displacement)
```

4.8.6 Bit manipulation instructions

This section describes the bit manipulation instructions. Next table lists the instructions described in this section. See the RH850 product user's manual and architecture edition for details.

Table 4-39. Bit Manipulation Instructions

Instruction	Meanings
set1	Sets bit
clr1	Clears bit
not1	Inverts bit
tst1	Tests bit

set1

Set s bit.

[Syntax]

- set1 bit#3, disp[reg1]
- set1 reg2, [reg1]

The following can be specified for disp:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

Caution The disp cannot be specified in syntax "set1 reg2, [reg1]".

[Function]

- Syntax "set1 bit#3, disp[reg1]"
  Sets the bit specified by the first operand of the data indicated by the address specified by the second operand. The bits other than the one specified are not affected.
- Syntax "set1 reg2, [reg1]"
  Sets the bit specified by the register value specified by the first operand of the data indicated by the address specified by the register value of the second operand. The bits other than the one specified are not affected.

[Description]

- If the following is specified for disp, the assembler generates one set1 machine instruction[Note].

(a) Absolute expression having a value in the range of -32,768 to +32,767

`set1 bit#3, disp16[reg1]`	`set1 bit#3, disp16[reg1]`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`set1 bit#3, $label[reg1]`	`set1 bit#3, $label[reg1]`

(c) Relative expression having !label or %label

`set1 bit#3, !label[reg1]`	`set1 bit#3, !label[reg1]`
`set1 bit#3, %label[reg1]`	`set1 bit#3, %label[reg1]`

(d) Expression with HIGHW, LOWW, or HIGHW1

`set1 bit#3, HIGHW(value)[reg1]`	`set1 bit#3, HIGHW(value)[reg1]`
`set1 bit#3, LOWW(value)[reg1]`	`set1 bit#3, LOWW(value)[reg1]`
`set1 bit#3, HIGHW1(value)[reg1]`	`set1 bit#3, HIGHW1(value)[reg1]`

Note The set1 machine instruction takes an immediate value in the range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF) as the displacement.

- If any of the following is specified as disp, the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

`set1 bit#3, disp[reg1]`	`movhi HIGHW1(disp), reg1, r1` `set1 bit#3, LOWW(disp)[r1]`

(b) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`set1 bit#3, #label[reg1]`	`movhi HIGHW1(#label), reg1, r1` `set1 bit#3, LOWW(#label)[r1]`
`set1 bit#3, label[reg1]`	`movhi HIGHW1(label), reg1, r1` `set1 bit#3, LOWW(label)[r1]`
`set1 bit#3, $label[reg1]`	`movhi HIGHW1($label), reg1, r1` `set1 bit#3, LOWW($label)[r1]`

- If disp is omitted, the assembler assumes 0.
- If a relative expression with #label, or a relative expression with #label and with HIGHW, LOWW, or HIGHW1 applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [r0] is specified.
- If a relative expression with $label, or a relative expression with $label and with HIGHW, LOWW, or HIGHW1 applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [gp] is specified.

[Flag]

CY	---
OV	---
S	---
Z	1 if the specified bit is 0, 0 if not[Note]
SAT	---

Note The flag values shown here are those existing prior to the execution of this instruction, not those after the execution.

clr1

Clears bit.

[Syntax]

- clr1 bit#3, disp[reg1]
- clr1 reg2, [reg1]

The following can be specified for disp:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

Caution The disp cannot be specified in syntax "clr1 reg2, [reg1]".

[Function]

- Syntax "clr1 bit#3, disp[reg1]"
  Clears the bit specified by the first operand of the data indicated by the address specified by the second operand. The bits other than the one specified are not affected.
- Syntax "clr1 reg2, [reg1]"
  Clears the bit specified by the register value specified by the first operand of the data indicated by the address specified by the register value of the second operand. The bits other than the one specified are not affected.

[Description]

- If the following is specified as disp, the assembler generates one clr1 machine instruction[Note].

(a) Absolute expression having a value in the range of -32,768 to +32,767

`clr1 bit#3, disp16[reg1]`	`clr1 bit#3, disp16[reg1]`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`clr1 bit#3, $label[reg1]`	`clr1 bit#3, $label[reg1]`

(c) Relative expression having !label or %label

`clr1 bit#3, !label[reg1]`	`clr1 bit#3, !label[reg1]`
`clr1 bit#3, %label[reg1]`	`clr1 bit#3, %label[reg1]`

(d) Expression with HIGHW, LOWW, or HIGHW1

`clr1 bit#3, HIGHW(value)[reg1]`	`clr1 bit#3, HIGHW(value)[reg1]`
`clr1 bit#3, LOWW(value)[reg1]`	`clr1 bit#3, LOWW(value)[reg1]`
`clr1 bit#3, HIGHW1(value)[reg1]`	`clr1 bit#3, HIGHW1(value)[reg1]`

Note The clr1 machine instruction takes an immediate value in the range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF) as the displacement.

- If any of the following is specified as disp, the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

`clr1 bit#3, disp[reg1]`	`movhi HIGHW1(disp), reg1, r1` `clr1 bit#3, LOWW(disp)[r1]`

(b) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`clr1 bit#3, #label[reg1]`	`movhi HIGHW1(#label), reg1, r1` `clr1 bit#3, LOWW(#label)[r1]`
`clr1 bit#3, label[reg1]`	`movhi HIGHW1(label), reg1, r1` `clr1 bit#3, LOWW(label)[r1]`
`clr1 bit#3, $label[reg1]`	`movhi HIGHW1($label), reg1, r1` `clr1 bit#3, LOWW($label)[r1]`

- If disp is omitted, the assembler assumes 0.
- If a relative expression with #label or a relative expression with #label and with HIGHW, LOWW, or HIGHW1 applied is specified as disp, [reg1] that follows the expression can be omitted. If omitted, the assembler assumes [r0] to be specified.
- If a relative expression with $label, or a relative expression with $label and with HIGHW, LOWW, or HIGHW1 applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [gp] is specified.

[Flag]

CY	---
OV	---
S	---
Z	1 if the specified bit is 0, 0 if not[Note]
SAT	---

Note The flag values shown here are those existing prior to the execution of this instruction, not those after the execution.

not1

Inverts bit.

[Syntax]

- not1 bit#3, disp[reg1]
- not1 reg2, [reg1]

The following can be specified for disp:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

Caution The disp cannot be specified in syntax "not1 reg2, [reg1]".

[Function]

- Syntax "not1 bit#3, disp[reg1]"
  Inverts the bit specified by the first operand (0 to 1 or 1 to 0) of the data indicated by the address specified by the second operand. The bits other than the one specified are not affected.
- Syntax "not1 reg2, [reg1]"
  Inverts the bit specified by the register value specified by the first operand (0 to 1 or 1 to 0) of the data indicated by the address specified by the register value of the second operand. The bits other than the one specified are not affected.

[Description]

- If the following is specified for disp, the assembler generates one not1 machine instruction[Note].

(a) Absolute expression having a value in the range of -32,768 to +32,767

`not1 bit#3, disp16[reg1]`	`not1 bit#3, disp16[reg1]`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`not1 bit#3, $label[reg1]`	`not1 bit#3, $label[reg1]`

(c) Relative expression having !label or %label

`not1 bit#3, !label[reg1]`	`not1 bit#3, !label[reg1]`
`not1 bit#3, %label[reg1]`	`not1 bit#3, %label[reg1]`

(d) Expression with HIGHW, LOWW, or HIGHW1

`not1 bit#3, HIGHW(value)[reg1]`	`not1 bit#3, HIGHW(value)[reg1]`
`not1 bit#3, LOWW(value)[reg1]`	`not1 bit#3, LOWW(value)[reg1]`
`not1 bit#3, HIGHW1(value)[reg1]`	`not1 bit#3, HIGHW1(value)[reg1]`

Note The not1 machine instruction takes an immediate value in the range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF) as the displacement.

- If any of the following is specified as disp, the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

`not1 bit#3, disp[reg1]`	`movhi HIGHW1(disp), reg1, r1` `not1 bit#3, LOWW(disp)[r1]`

(b) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`not1 bit#3, #label[reg1]`	`movhi HIGHW1(#label), reg1, r1` `not1 bit#3, LOWW(#label)[r1]`
`not1 bit#3, label[reg1]`	`movhi HIGHW1(label), reg1, r1` `not1 bit#3, LOWW(label)[r1]`
`not1 bit#3, $label[reg1]`	`movhi HIGHW1($label), reg1, r1` `not1 bit#3, LOWW($label)[r1]`

- If disp is omitted, the assembler assumes 0.
- If a relative expression with #label, or a relative expression with #label and with HIGHW, LOWW, or HIGHW1 applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [r0] is specified.
- If a relative expression with $label, or a relative expression with $label and with HIGHW, LOWW, or HIGHW1 applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [gp] is specified.

[Flag]

CY	---
OV	---
S	---
Z	1 if the specified bit is 0, 0 if not[Note]
SAT	---

Note The flag values shown here are those existing prior to the execution of this instruction, not those after the execution.

tst1

Tests bit.

[Syntax]

- tst1 bit#3, disp[reg1]
- tst1 reg2, [reg1]

The following can be specified for disp:

- Absolute expression having a value of up to 32 bits
- Relative expression
- Either of the above expressions with HIGHW, LOWW, or HIGHW1 applied

Caution The disp cannot be specified in syntax "tst1 reg2, [reg1]".

[Function]

- Syntax "tst1 bit#3, disp[reg1]"
  Sets only a flag according to the value of the bit specified by the first operand of the data indicated by the address specified by the second operand. The value of the second operand and the specified bit are not changed.
- Syntax "tst1 reg2, [reg1]"
  Sets only a flag according to the value of the bit of the register value specified by the first operand of the data indicated by the address specified by the second operand. The value of the second operand and the specified bit are not changed.

[Description]

- If the following is specified for disp, the assembler generates one tst1 machine instruction[Note].

(a) Absolute expression having a value in the range of -32,768 to +32,767

`tst1 bit#3, disp16[reg1]`	`tst1 bit#3, disp16[reg1]`

(b) Relative expression having $label for a label having a definition in the sdata/sbss-attribute section

`tst1 bit#3, $label[reg1]`	`tst1 bit#3, $label[reg1]`

(c) Relative expression having !label or %label

`tst1 bit#3, !label[reg1]`	`tst1 bit#3, !label[reg1]`
`tst1 bit#3, %label[reg1]`	`tst1 bit#3, %label[reg1]`

(d) Expression with HIGHW, LOWW, or HIGHW1

`tst1 bit#3, HIGHW(value)[reg1]`	`tst1 bit#3, HIGHW(value)[reg1]`
`tst1 bit#3, LOWW(value)[reg1]`	`tst1 bit#3, LOWW(value)[reg1]`
`tst1 bit#3, HIGHW1(value)[reg1]`	`tst1 bit#3, HIGHW1(value)[reg1]`

Note The tst1 machine instruction takes an immediate value in the range of -32,768 to +32,767 (0xFFFF8000 to 0x7FFF) as the displacement.

- If any of the following is specified as disp, the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression having a value exceeding the range of -32,768 to +32,767

`tst1 bit#3, disp[reg1]`	`movhi HIGHW1(disp), reg1, r1` `tst1 bit#3, LOWW(disp)[r1]`

(b) Relative expression having #label or label, or that having $label for a label having no definition in the sdata/sbss-attribute section

`tst1 bit#3, #label[reg1]`	`movhi HIGHW1(#label), reg1, r1` `tst1 bit#3, LOWW(#label)[r1]`
`tst1 bit#3, label[reg1]`	`movhi HIGHW1(label), reg1, r1` `tst1 bit#3, LOWW(label)[r1]`
`tst1 bit#3, $label[reg1]`	`movhi HIGHW1($label), reg1, r1` `tst1 bit#3, LOWW($label)[r1]`

- If disp is omitted, the assembler assumes 0.
- If a relative expression with #label, or a relative expression with #label and with HIGHW, LOWW, or HIGHW1 applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [r0] is specified.
- If a relative expression with $label, or a relative expression with $label and with HIGHW, LOWW, or HIGHW1 applied is specified as disp, [reg1] can be omitted. If omitted, the assembler assumes that [gp] is specified.

[Flag]

CY	---
OV	---
S	---
Z	1 if the specified bit is 0, 0 if not
SAT	---

4.8.7 Stack manipulation instructions

This section describes the stack manipulation instructions. Next table lists the instructions described in this section. See the RH850 product user's manual and architecture edition for details.

Table 4-40. Stack Manipulation Instructions

Instruction	Meanings
push	Pushes to stack area (single register)
pushm	Pushes to stack area (multiple registers)
pop	Pops from stack area (single register)
popm	Pops from stack area (multiple registers)

push

Pushes to stack area (single register).

[Syntax]

push reg

[Function]

Pushes the value of the register specified by the operand to the stack area.

[Description]

- When the push instruction is executed, the assembler executes instruction expansion to generate two or more machine instructions.

`push reg`	`add -4, sp` `st.w reg, [sp]`

[Flag]

CY	1 if a carry occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

Caution Instruction expansion is performed, and set via an add instruction.

pushm

Pushes to stack area (multiple registers).

[Syntax]

pushm reg1, reg2, ..., regN

[Function]

Pushes the values of the registers specified by the operand to the stack area. Up to 32 registers can be specified by the operand.

[Description]

- When the pushm instruction is executed, the assembler executes instruction expansion to generate two or more machine instructions.
  - When there are four or fewer registers.

`pushm reg1, reg2, ..., regN`	`add -4 * N, sp`
	`st.w regN, 4 * (N - 1)[sp]`
	`:`
	`st.w reg2, 4 * 1[sp]`
	`st.w reg1, 4 * 0[sp]`

  - When there are five or more registers.

`pushm reg1, reg2, ..., regN`	`addi -4 * N, sp, sp`
	`st.w regN, 4 * (N - 1)[sp]`
	`:`
	`st.w reg2, 4 * 1[sp]`
	`st.w reg1, 4 * 0[sp]`

[Flag]

CY	1 if a carry occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

Caution Instruction expansion is performed, and set via an add/addi instruction.

pop

Pops from stack area (single register).

[Syntax]

pop reg

[Function]

Pops the value of the register specified by the operand from the stack area.

[Description]

- When the pop instruction is executed, the assembler executes instruction expansion to generate two or more machine instructions.

`pop reg`	`ld.w [sp], reg` `add 4, sp`

[Flag]

CY	1 if a carry occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

Caution Instruction expansion is performed, and set via an add instruction.

popm

Pops from stack area (multiple registers).

[Syntax]

popm reg1, reg2, ..., regN

[Function]

Pops the values of the registers specified by the operand from the stack area in the sequence in which the registers are specified. Up to 32 registers can be specified by the operand.

[Description]

- When the popm instruction is executed, the assembler executes instruction expansion to generate two or more machine instructions.
  - When there are three or fewer registers.

`popm reg1, reg2, ..., regN`	`ld.w 4 * 0[sp], reg1`
	`ld.w 4 * 1[sp], reg2`
	`:`
	`ld.w 4 * (N - 1)[sp], regN`
	`add 4 * N, sp`

  - When there are four or more registers.

`popm reg1, reg2, ..., regN`	`ld.w 4 * 0[sp], reg1`
	`ld.w 4 * 1[sp], reg2`
	`:`
	`ld.w 4 * (N - 1)[sp], regN`
	`addi 4 * N, sp, sp`

[Flag]

CY	1 if a carry occurs from MSB (Most Significant Bit), 0 if not
OV	1 if Integer-Overflow occurs, 0 if not
S	1 if the result is negative, 0 if not
Z	1 if the result is 0, 0 if not
SAT	---

Caution Instruction expansion is performed, and set via an add/addi instruction.

4.8.8 Special instructions

This section describes the special instructions.

See the RH850 product user's manual and architecture edition for details.

Table 4-41. Special Instructions

Instruction	Meanings
ldsr	Loads to system register
stsr	Stores contents of system register
ldl.w	Load to start atomic word data manipulation
stc.w	Conditional storage when atomic word data manipulation is complete
cll	Link for atomic manipulation is canceled
di	Disables maskable interrupt
ei	Enables maskable interrupt
reti	Returns from trap or interrupt routine
eiret	Returns from EI level exception
feret	Returns from FE level exception
halt	Stops the processor
trap	Software trap
fetrap	FE level software exception
nop	No operation
switch	Table reference branch
callt	Table reference call
ctret	Returns from callt
caxi	Comparison and swap
rie	Reserved instruction exception
syncm	Memory synchronize instruction
syncp	Pipeline synchronize instruction
synce	Exception synchronization instruction
synci	Instruction pipeline synchronization instruction
prepare	Generates stack frame (preprocessing of function)
dispose	Deletes stack frame (post processing of function)
syscall	System call exception
pushsp	Push from the stack
popsp	Pop from the stack
snooze	Snooze

ldsr

Loads to system register.

[Syntax]

- ldsr reg, regID
- ldsr reg, regID, selID

The following can be specified as regID and selID:

- Absolute expression having a value of up to 5 bits

[Function]

- Syntax "ldsr reg, regID"
  Stores the value of the register specified by the first operand in the system register[Note] indicated by the system register number specified by the second operand.
- Syntax "ldsr reg, regID, selID"
  Stores the register value specified in the first operand into the system register[Note] indicated by the system-register number specified in the second operand, and the group number specified in the third operand.
  If selID is omitted, it is assumed that selID=0 was specified.

Note For details of the system registers, see the Relevant Device's Hardware User's Manual provided with the each device.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

Caution **If the program status word (PSW) is specified as the system register, the value of the corresponding bit of reg is set as each flag.**

[Caution]

- If an absolute expression having a value exceeding the range of 0 to 31 is specified as regID, the assembler outputs the following message, then continues assembling using the lower 5 bits[Note] of the specified value.

```
W0550011 : illegal operand (range error in immediate)
```

Note The ldsr machine instruction takes an immediate value in the range of 0 to 31 (0x0 to 0x1F) as the second operand.

- If a reserved register number, the number of a register which cannot be accessed (such as ECR) or the number of a register which can be accessed only in the debug mode is specified as regID, the assembler outputs the following message and continues assembling as is.

```
W0550018 : illegal regID for ldsr
```

stsr

Stores contents of system register.

[Syntax]

- stsr regID, reg
- stsr regID, reg, selID

The following can be specified as regID and selID:

- Absolute expression having a value of up to 5 bits

[Function]

- Syntax "stsr regID, reg"
  Stores the value of the system register[Note] indicated by the system register number specified by the first operand, to the register specified by the second operand.
- Syntax "stsr regID, reg, selID"
  Stores the value of the system register[Note] indicated by the system-register number specified in the first operand and the group number specified in the third operand into the register specified in the second operand.
  If selID is omitted, it is assumed that selID=0 was specified.

Note For details of the system registers, see the Relevant Device's Hardware User's Manual provided with the each device.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of 0 to 31 is specified as regID and selID, the assembler outputs the following message, then continues assembling using the lower 5 bits[Note] of the specified value.

```
W0550011 : illegal operand (range error in immediate)
```

Note The stsr machine instruction takes an immediate value in the range of 0 to 31 (0x0 to 0x1F) as the first operand.

- If a reserved register number or the number of a register which can be accessed only in the debug mode is specified as regID, the assembler outputs the following message and continues assembling as is.

```
W0550018 : illegal regID for ldsr
```

ldl.w

Load to start atomic word data manipulation (Load Linked)

[Syntax]

- ldl.w [reg1], reg2

[Function]

In order to perform an atomic read-modify-write operation, word data is read from the memory and stored in general-purpose register reg2. A link is then generated corresponding to the address range that includes the specified address.

Subsequently, if a specific condition is satisfied before an stc.w instruction is executed for this ldl.w instruction, the link will be deleted. If an stc.w instruction is executed after the link has been deleted, stc.w execution will fail.

If an stc.w instruction is executed while the link is still available, stc.w execution will succeed. The link is also deleted in this case.

The ldl.w and stc.w instructions can be used to accurately update the memory in a multi-core system.

Remark Use the ldl.w and stc.w instructions instead of the caxi instruction if an atomic guarantee is required when updating the memory in a multi-core system.

[Description]

- The assembler generates one ldl.w machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

stc.w

Conditional storage when atomic word data manipulation is complete (Store Conditional)

[Syntax]

- stc.w reg2, [reg1]

[Function]

This instruction can only be executed successfully if a link exists that corresponds to the specified address. If a corresponding link exists, the word data of general-purpose register reg2 is stored in the memory and an atomic read-modify-write is executed.

If the corresponding link has been lost, the data is not stored in the memory and execution of this instruction fails.

Whether execution of the stc.w instruction has succeeded or not can be ascertained by checking the contents of general-purpose register reg2 after the instruction has been executed.

If execution of the stc.w instruction was successful, general-purpose register reg3 will be set (1). If execution failed, reg2 will be cleared (0).

This instruction can be used together with the ldl.w instruction to ensure accurate updating of the memory in a multi-core system.

Remark Use the ldl.w and stc.w instructions instead of the caxi instruction if an atomic guarantee is required when updating the memory in a multi-core system.

[Description]

- The assembler generates one stc.w machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

cll

Link for atomic manipulation is canceled.

[Syntax]

- cll

[Function]

This instruction explicitly eliminates the link generated by the ldl.w instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---
ID	---

di

Disables maskable interrupt.

[Syntax]

- di

[Function]

Sets the ID bit of the PSW to 1 and disables acknowledgement of maskable interrupts since this instruction has already been executed.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---
ID	1

ei

Enables maskable interrupt.

[Syntax]

- ei

[Function]

Sets the ID bit of the PSW to 0, and enables acknowledgment of maskable interrupt from the next instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---
ID	0

reti

Returns from trap or interrupt routine.

[Syntax]

- reti

[Function]

Returns from a trap or interrupt routine[Note].

Note For details of the function, see the Relevant Device's Architecture User's Manual of each devic

[Flag]

CY	Extracted value
OV	Extracted value
S	Extracted value
Z	Extracted value
SAT	Extracted value

eiret

Returns from EI level exception (Return from Trap or Interrupt)

[Syntax]

- eiret

[Function]

Returns execution from an EI level exception. The return PC and PSW are loaded from the EIPC and EIPSW registers and set in the PC and PSW, and control is passed.

If EP = 0, it means that interrupt (EIINT*n*) processing has finished, so the corresponding bit of the ISPR register is cleared.

[Description]

- The assembler generates one eiret machine instruction.

[Flag]

CY	Value read from EIPSW is set
OV	Value read from EIPSW is set
S	Value read from EIPSW is set
Z	Value read from EIPSW is set
SAT	Value read from EIPSW is set

feret

Returns from FE level exception (Return from Trap or Interrupt)

[Syntax]

- feret

[Function]

Returns execution from an FE level exception. The return PC and PSW are loaded from the FEPC and FEPSW registers and set in the PC and PSW, and control is passed.

[Description]

- The assembler generates one feret machine instruction.

[Flag]

CY	Value read from FEPSW is set
OV	Value read from FEPSW is set
S	Value read from FEPSW is set
Z	Value read from FEPSW is set
SAT	Value read from FEPSW is set

halt

Stops the processor.

[Syntax]

- halt

[Function]

Stops the processor and sets it in the HALT status. The HALT status can be released by a maskable interrupt, NMI, or reset.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

trap

Software trap.

[Syntax]

- trap vector

The following can be specified for vector:

- Absolute expression having a value of up to 5 bits

[Function]

Causes a software trap[Note].

Note For details of the function, see the Relevant Device's Architecture User's Manual of each device.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value falling outside the range of 0 to 31 is specified as vector, the assembler outputs the following message, continuing assembling using the lower 5 bits[Note] of the specified value.

```
W0550011 : illegal operand (range error in immediate)
```

Note The trap machine instruction takes an immediate value in the range of 0 to 31 (0x0 to 0x1F) as an operand.

fetrap

FE level software exception (FE-level Trap)

[Syntax]

- fetrap

[Function]

Saves the contents of the return PC (address of the instruction next to the FETRAP instruction) and the current contents of the PSW to FEPC and FEPSW, respectively, stores the exception cause code in the FEIC register, and updates the PSW according to the exception causes. Execution then branches to the exception handler address and exception handling is started.

Table 4-42. Correspondence between vector4 and Exception Cause Codes and Exception Handler Address Offset shows the correspondence between vector4 and exception cause codes and exception handler address offset. Exception handler addresses are calculated based on the offset addresses listed in Table 4-42. Correspondence between vector4 and Exception Cause Codes and Exception Handler Address Offset.

Table 4-42. Correspondence between vector4 and Exception Cause Codes and Exception Handler Address Offset

vector4	Exception Cause Code	Offset Address
0H	Not specifiable	
1H	00000031H	30H
2H	00000032H	
(Omission)		
FH	0000003FH	

[Description]

- The assembler generates one fetrap machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

nop

No operation.

[Syntax]

- nop

[Function]

Nothing is executed. This instruction can be used to allocate an area during an instruction sequence or to insert a delay cycle during instruction execution.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

switch

Table reference branch.

[Syntax]

switch reg

[Function]

Performs processing in the following sequence.

(1) Adds the value resulting from logically shifting the value specified by the operand 1 bit to the left to the first address of the table (address following the switch instruction) to generate a table entry address.

(2) Loads signed halfword data from the generated table entry address.

(3) Logically shifts the loaded value 1 bit to the left and sign-extends it to word length. Then adds the first address of the table to it to generate an address

(4) Branches to the generated address.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If r0 is specified by reg, the assembler outputs the following message and stops assembling.

E0550239 : Illegal operand (cannot use r0 as source in RH850 mode).

callt

Table reference call.

[Syntax]

- callt imm6

The following can be specified as imm6:

- Absolute expression having a value of up to 6 bits

[Function]

Performs processing in the following sequence[Note]

(1) Saves the values of the return PC and PSW to CTPC and CTPSW.

(2) Generates a table entry address by shifting the value specified by the operand 1 bit to the left as an offset value from CTBP(CALLT Base Pointer) and by adding it to the CTBP value.

(3) Loads unsigned halfword data from the generated table entry address.

(4) Adds the loaded value to the CTBP value to generate an address.

(5) Branches to the generated address.

Note For details of the system registers, see the Relevant Device's Architecture User's Manual of each device.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

ctret

Returns from callt.

[Syntax]

- ctret

[Function]

Returns from the processing by callt. Performs the processing in the following sequence[Note]:

(1) Extracts the return PC and PSW from CTPC and CTPSW.

(2) Sets the extracted values in the PC and PSW and transfers control.

Note For details of the system registers, see the Relevant Device's Architecture User's Manual of each device.

[Flag]

CY	Extracted value
OV	Extracted value
S	Extracted value
Z	Extracted value
SAT	Extracted value

caxi

Comparison and swap (Compare and Exchange for Interlock)

[Syntax]

- caxi [reg1], reg2, reg3

[Function]

Word data is read from the specified address and compared with the word data in general-purpose register reg2, and the result is indicated by flags in the PSW. Comparison is performed by subtracting the read word data from the word data in general-purpose register reg2. If the comparison result is "0", word data in general-purpose register reg3 is stored in the generated address, otherwise the read word data is stored in the generated address.

Afterward, the read word data is stored in general-purpose register reg3. General-purpose registers reg1 and reg2 are not affected.

[Description]

- The assembler generates one caxi machine instruction.

[Flag]

CY	"1" if a borrow occurs in the result operation; otherwise, "0"
OV	"1" if overflow occurs in the result operation; otherwise, "0"
S	"1" if result is negative; otherwise, "0"
Z	"1" if result is 0; otherwise, "0"
SAT	---

rie

Reserved Instruction exception (Reserved Instruction Exception)

[Syntax]

- rie
- rie imm5, imm4

The following can be specified as imm5:

- Absolute expression having a value of up to 5 bits

The following can be specified as imm4:

- Absolute expression having a value of up to 4 bits

[Function]

Saves the contents of the return PC (address of the RIE instruction) and the current contents of the PSW to FEPC and FEPSW, respectively, stores the exception cause code in the FEIC register, and updates the PSW according to the exception causes. Execution then branches to the exception handler address and exception handling is started.

Exception handler addresses are calculated based on the offset address 60H.

[Description]

- The assembler generates one rie machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

syncm

Memory synchronize instruction (Synchronize Memory)

[Syntax]

- syncm

[Function]

Synchronizes the CPU execution pipeline and memory accesses.

"Synchronization" refers to the status where the result of preceding memory accesses can be referenced by any master device within the system.

In cases such as when buffering is used to delay memory accesses and synchronization of all memory accesses has not occurred, the SYNCM instruction does not complete and waits for the synchronization.

The subsequent instructions will not be executed until the SYNCM instruction execution is complete.

This instruction can be used to implement "synchronization primitives" in a multi-processing environment when the function described above is provided by the system.

[Description]

- The assembler generates one syncm machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

syncp

Pipeline synchronize instruction (Synchronize Pipline)

[Syntax]

- syncp

[Function]

Waits until execution of all previous instructions is completed before being executed.

[Description]

- The assembler generates one syncp machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

synce

Exception synchronization instruction (Synchronize Exceptions)

[Syntax]

- synce

[Function]

Waits for the synchronization of all preceding exceptions before starting execution.

It does not perform any operation but is completed when its execution is started.

"Exception synchronization" means that all exceptions that are generated by the preceding instructions are notified to the CPU and are kept waiting until their priority is judged. If a condition of acknowledging exceptions is satisfied before this instruction is executed, therefore, all imprecise exceptions (FPI exceptions) that are generated because of the preceding instructions are always acknowledged before execution of this instruction is completed.

This instruction can be used to guarantee completion of exception handling by the preceding task before a task is changed or terminated in a multi-processing environment.

[Description]

- The assembler generates one synce machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

synci

Instruction pipeline synchronization instruction (Synchronize Instruction Pipeline)

[Syntax]

- synci

[Function]

Makes subsequent instructions wait until all the instructions ahead of this instruction have finished executing. The instructions executed after the synci instruction are guaranteed to adapt to the effects produced by the execution of the instructions preceding synci. This instruction can be used to realize "self-programming code" to overwrite instructions in the memory.

Remark The synci instruction clears the CPU instruction fetch pipeline so that subsequently executed instructions are re-fetched.
If the CPU includes an instruction cache, the instruction cache must be disabled to enable the realization of this self-programming code.

[Description]

- The assembler generates one synci machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

prepare

Generates stack frame (preprocessing of function).

[Syntax]

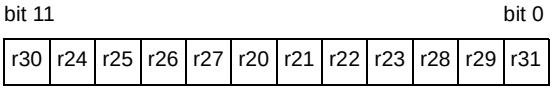
- prepare list, imm1
- prepare list, imm1, imm2
- prepare list, imm1, sp

The following can be specified as imm1/imm2:

- Absolute expression having a value of up to 32 bits

list specifies the 12 registers that can be pushed by the prepare instruction.The following can be specified as list.

- Register
  Specify the registers (r20 to r31) to be pushed, delimiting each with a comma.
- Absolute expression having a value of up to 12 bits
  The 12 bits and 12 registers correspond as follows:



The following two specifications are equivalent.

`prepare r26, r29, r31, 0x10`	`prepare 0x103, 0x10`

[Function]

The prepare instruction performs the preprocessing of a function.

- Syntax "prepare list, imm1"

(a) Pushes one of the registers specified by the first operand and subtracts 4 from the stack pointer (sp).

(b) Repeatedly performs (a) until all the registers specified by the first operand have been pushed.

(c) Subtracts the value of the absolute expression specified by the second operand from sp[Note] and sets sp in the register saving area.

- Syntax "prepare list, imm1, imm2"

(a) Pushes one of the registers specified by the first operand and subtracts 4 from sp.

(b) Repeatedly performs (a) until all the registers specified by the first operand have been pushed.

(c) Subtracts the value of the absolute expression specified by the second operand from sp[Note] and sets sp to the register saving area.

(d) Sets the value of the absolute expression specified by the third operand in ep.

- Syntax "prepare list, imm1, sp"

(a) Pushes one of the registers specified by the first operand and subtracts 4 from sp.

(b) Repeatedly performs (a) until all the registers specified by the first operand have been pushed.

(c) Subtracts the value of the absolute expression specified by the second operand from sp[Note] and sets sp in the register saving area.

(d) Sets the value of sp specified by the third operand in ep.

Note Since the value actually subtracted from sp by the machine instruction is imm1 shifted 2 bits to the left, the assembler shifts the specified imm1 2 bits to the right in advance and reflects it in the code.

[Description]

- If the following is specified for imm1, the assembler generates one prepare machine instruction.

(a) Absolute expression having a value in the range of 0 to 127

`prepare list, imm1`	`prepare list, imm1`
`prepare list, imm1, imm2`	`prepare list, imm1, imm2`
`prepare list, imm1, sp`	`prepare list, imm1, sp`

- When the following is specified as imm1, the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression exceeding the range of 0 to 127, but within the range of 0 to 32,767

`prepare list, imm1`	`prepare list, 0` `movea -imm1, sp, sp`
`prepare list, imm1, imm2`	`prepare list, 0, imm2` `movea -imm1, sp, sp`
`prepare list, imm1, sp`	`prepare list, 0, sp` `movea -imm1, sp, sp`

(b) Absolute expression having a value exceeding the range of 0 to 32,767

`prepare list, imm1`	`prepare list, 0`
	`mov imm1, r1`
	`sub r1, sp`

`prepare list, imm1, imm2`	`prepare list, 0, imm2`
	`mov imm1, r1`
	`sub r1, sp`

`prepare list, imm1, sp`	`prepare list, 0, sp`
	`mov imm1, r1`
	`sub r1, sp`

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

dispose

Deletes stack frame (post processing of function).

[Syntax]

- dispose imm, list
- dispose imm, list, [reg]

The following can be specified for imm:

- Absolute expression having a value of up to 32 bits

The following can be specified as list. list specifies the 12 registers that can be popped by the dispose instruction.

- Register
  Specify the registers (r20 to r31) to be popped, delimiting each with a comma.
- Absolute expression having a value of up to 12 bits
  The 12 bits and 12 registers correspond as follows:

bit 11											bit 0
r30	r24	r25	r26	r27	r20	r21	r22	r23	r28	r29	r31

The following two specifications are equivalent.

`dispose 0x10, r26, r29, r31`	`dispose 0x10, 0x103`

[Function]

The dispose instruction performs the postprocessing of a function.

- Syntax "dispose imm, list"

(a) Adds the value of the absolute expression specified by the first operand to the stack pointer (sp)[Note] and sets sp in the register saving area.

(b) Pops one of the registers specified by the second operand and adds 4 to sp.

(c) Repeatedly executes (b) until all the registers specified by the second operand have been popped.

- Syntax "dispose imm, list, [reg]"

(a) Adds the value of the absolute expression specified by the first operand to the stack pointer (sp)[Note] and sets sp in the register saving area.

(b) Pops one of the registers specified by the second operand and adds 4 to sp.

(c) Repeatedly executes (b) until all the registers specified by the second operand have been popped.

(d) Sets the register value specified by the third operand in the program counter (PC).

Note Since the value actually added to sp by the machine instruction is imm shifted 2 bits to the left, the assembler shifts the specified imm 2 bits to the right in advance and reflects it in the code.

[Description]

- If the following is specified for imm, the assembler generates one dispose machine instruction.

(a) Absolute expression having a value in the range of 0 to 127

`dispose imm, list`	`dispose imm, list`
`dispose imm, list, [reg]`	`dispose imm, list, [reg]`

- If the following is specified for imm, the assembler executes instruction expansion to generate two or more machine instructions.

(a) Absolute expression exceeding the range of 0 to 127, but within the range of 0 to 32,767

`dispose imm, list`	`movea imm, sp, sp` `dispose 0, list`
`dispose imm, list, [reg]`	`movea imm, sp, sp` `dispose 0, list, [reg]`

(b) Absolute expression having a value exceeding the range of 0 to 32,767

`dispose imm, list`	`mov imm, r1`
	`add r1, sp`
	`dispose 0, list, [reg]`

`dispose imm, list, [reg]`	`mov imm, r1`
	`add r1, sp`
	`dispose 0, list, [reg]`

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If r0 is specified by the [reg] in syntax "dispose imm, list, [reg]", the assembler outputs the following message and stops assembling.

E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).

syscall

System call exception (System Call)

[Syntax]

- syscall vector

The following can be specified as vector:

- Absolute expression having a value of up to 8 bits

[Function]

This instruction calls the system service of an OS.

(1) Saves the contents of the return PC (address of the instruction next to the syscall instruction) and PSW to EIPC and EIPSW.

(2) Stores the exception cause code corresponding to vector in the EIIC register.
The exception cause code is the value of vector plus 8000H.

(3) Updates the PSW according to the exception causes.

(4) Generates a 32-bit table entry address by adding the value of the SCBP register and vector that is logically shifted 2 bits to the left and zero-extended to a word length.
If vector is greater than the value specified by the SIZE bit of system register SCCFG; however, vector that is used for the above addition is handled as 0.

(5) Loads the word of the address generated in (4).

(6) Generates a 32-bit target address by adding the value of the SCBP register to the data in (5).

(7) Branches to the target address generated in (6).

[Description]

- The assembler generates one syscall machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of 0 to 255 is specified as vector, the assembler outputs the following message and continues assembling by using the lower 8 bits[Note] of the specified value.

```
W0550011 : Illegal operand (range error in immediate).
```

Note The syscall machine instruction takes an immediate value in the range of 0 to 255 (0x0 to 0xFF)as the operand.

- This instruction is dedicated to calling the system service of an OS. For how to use it in the user program, see the Function Specification of each OS.
- In the syscall instruction memory read operation executed in order to read the table, memory protection is performed with the supervisor privilege.

pushsp

Push from the stack (Push Registers from Stack)

[Syntax]

- pushsp rh, rt

The following can be specified as rt and rh:

- General-purpose registers r0 - r31

[Function]

Stores general-purpose register rh to rt in the stack in ascending order (rh, rh +1, rh + 2, ..., rt). After all the specified registers have been stored, sp is updated (decremented).

Remark The lower two bits of the address specified by sp are masked by 0.
If an exception is acknowledged before sp is updated, instruction execution is halted and exception handling is executed with the start address of this instruction used as the return address. The pushsp instruction is then executed again (The sp value from before the exception handling is saved).

[Description]

- The assembler generates one pushsp machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If the relationship between the register numbers specified as rh and rt is rh > rt, the assembler outputs the following message.

```
E0550249 : Illegal syntax.
```

popsp

Pop from the stack (Pop Registers from Stack)

[Syntax]

- popsp rh, rt

The following can be specified as rt and rh:

- General-purpose registers r0 - r31

[Function]

Loads general-purpose register rt to rh from the stack in descending order (rt, rt - 1, rt - 2, ..., rh). After all the registers down to the specified register have been loaded, sp is updated (incremented).

Remark The lower two bits of the address specified by sp are masked by 0.
If an exception is acknowledged before sp is updated, instruction execution is halted and exception handling is executed with the start address of this instruction used as the return address. The popsp instruction is then executed again (The sp value from before the exception handling is saved).

[Description]

- The assembler generates one popsp machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

[Caution]

- If the relationship between the register numbers specified as rh and rt is rh > rt, the assembler outputs the following message.

```
E0550249 : Illegal syntax.
```

- If a register that includes sp (r3) is specified as the restore register (rh = 3 to 31), the value read from the memory is not stored in sp (r3). This allows the POPSP instruction to be correctly re-executed after execution has been halted.

snooze

Snooze (Snooze)

[Syntax]

- snooze

[Function]

Temporarily halts operation of the CPU for the period defined by the hardware specifications or when the CPU enters a specific state.

When the specified period has elapsed or the CPU exits the specified state, CPU operation automatically resumes and instruction execution begins from the next instruction.

The SNOOZE state is released under the following conditions:

- The predefined period of time passes
- A terminating exception occurs

Even if the conditions for acknowledging the above exceptions are not satisfied (due to the ID or NP value), as long as a SNOOZE mode release request exists, the SNOOZE state is released (for example, even if PSW.ID = 1, the SNOOZE state is released when INT0 occurs).

Note, however, that the SNOOZE mode will not be released if terminating exceptions are masked by the following mask settings, which are defined individually for each function:

- Terminating exceptions are masked by an interrupt channel mask setting specified by the interrupt controller[Note].
- Terminating exceptions are masked by a mask setting specified by using the floating-point operation exception enable bit.
- Terminating exceptions are masked by a mask setting defined by a hardware function other than the above.

Note This does not include masking specified by the ISPR and PMR registers.

[Description]

- The assembler generates one snooze machine instruction.

[Flag]

CY	---
OV	---
S	---
Z	---
SAT	---

4.8.9 Loop instructions

Next table lists the loop instructions.

See the RH850 product user's manual and architecture edition for details.

Table 4-43. Loop Instructions

Instruction	Meanings
loop	Loop

loop

Loop (Loop)

[Syntax]

- loop reg1, disp16

The following can be specified as disp16:

- Absolute expression having a value of up to 16 bits
- Relative expression having a PC offset reference of label
- label (PC offset)

[Function]

Updates the general-purpose register reg1 by adding -1 from its contents. If the contents after this update are not 0, the following processing is performed. If the contents are 0, the system continues to the next instruction.

- The result of logically shifting the 15-bit immediate data 1 bit to the left and zero-extending it to word length is subtracted from the current PC value, and then the control is transferred.
- -1 (0xFFFFFFFF) is added to general-purpose register reg1. The carry flag is updated in the same way as when the add instruction, not the sub instruction, is executed.

Remark "0" is implicitly used for bit 0 of the 16-bit displacement. Note that, because the current PC value used for calculation is the address of the first byte of this instruction, if the displacement value is 0, the branch destination is this instruction.

[Description]

- If any of the following is specified for disp16, the assembler generates one loop machine instruction.

(a) Absolute expression having a value in the range of 0 to 65535

(b) Relative expression that has a PC offset reference of a label having a definition in the same section of the same file as this instruction, and having a value in the range of 0 to 65535

[Flag]

CY	"1" if a carry occurs from MSB in the reg1 operation; otherwise, "0"
OV	"1" if an overflow occurs in the reg1 operation; otherwise, "0"
S	"1" if reg1 is negative; otherwise, "0"
Z	"1" if reg1 is 0; otherwise, "0"
SAT	---

[Caution]

- If an absolute expression having a value exceeding the range of 0 to 65535 or a relative expression having a PC offset reference of a label with a definition in the same section of the same file as this instruction and having a value exceeding the range of 0 to 65535 is specified as disp16, the assembler outputs the following message and stops assembling.

```
E0550230 : Illegal operand (range error in displacement).
```

- If an absolute expression having an odd-numbered value or a relative expression having a PC offset reference of a label with a definition in the same section of the same file as this instruction and having an odd-numbered value is specified as disp16, the assembler outputs the following message and stops assembling.

```
E0550226 : Illegal operand (must be even displacement).
```

- If r0 is specified as reg1 in the loop instruction, the assembler outputs the following message and stops assembling.

```
E0550240 : Illegal operand (cannot use r0 as destination in RH850 mode).
```

- Do not specify r0 for reg1.

4.8.10 Floating-point operation instructions

Next table lists the floating-point operation instructions.

See the RH850 product user's manual and architecture edition for details.

Table 4-44. Floating-point Operation Instructions (Basic Operation Instructions)

Instruction	Meanings
absf.d	Floating-point absolute value (double precision)
absf.s	Floating-point absolute value (single precision)
addf.d	Floating-point add (double precision)
addf.s	Floating-point add (single precision)
divf.d	Floating-point division (double precision)
divf.s	Floating-point division (single precision)
maxf.d	Floating-point maximum value (double precision)
maxf.s	Floating-point maximum value (single precision)
minf.d	Floating-point minimum value (double precision)
minf.s	Floating-point minimum value (single precision)
mulf.d	Floating-point multiplication (double precision)
mulf.s	Floating-point multiplication (single precision)
negf.d	Floating-point sign inversion (double precision)
negf.s	Floating-point sign inversion (single precision)
recipf.d	Reciprocal (double precision)
recipf.s	Reciprocal (single precision)
rsqrtf.d	Reciprocal of square root (double precision)
rsqrtf.s	Reciprocal of square root (single precision)
sqrtf.d	Square root (double precision)
sqrtf.s	Square root (single precision)
subf.d	Floating-point subtraction (double precision)
subf.s	Floating-point subtraction (single precision)

Table 4-45. Floating-point Operation Instructions (Expansion Basic Operation Instructions)

Instruction	Meanings
fmaf.s	Floating-point fused-multiply-add operation (single precision)
fmsf.s	Floating-point fused-multiply-subtract operation (single precision)
fnmaf.s	Floating-point fused-multiply-add operation (single precision)
fnmsf.s	Floating-point fused-multiply-add operation (single precision)

Table 4-46. Floating-point Operation Instructions (Exchange Instructions)

Instruction	Meanings
ceilf.dl	Conversion to fixed-point format (double precision)
ceilf.dw	Conversion to fixed-point format (double precision)
ceilf.dul	Conversion to unsigned fixed-point format (double precision)
ceilf.duw	Conversion to unsigned fixed-point format (double precision)
ceilf.sl	Conversion to fixed-point format (single precision)
ceilf.sw	Conversion to fixed-point format (single precision)
ceilf.sul	Conversion to unsigned fixed-point format (single precision)
ceilf.suw	Conversion to unsigned fixed-point format (single precision)
cvtf.dl	Conversion to fixed-point format (double precision)
cvtf.ds	Conversion to floating-point format (double precision)
cvtf.dul	Conversion to unsigned fixed-point format (double precision)
cvtf.duw	Conversion to unsigned fixed-point format (double precision)
cvtf.dw	Conversion to fixed-point format (double precision)
cvtf.hs	Conversion to floating-point format (single precision)
cvtf.ld	Conversion to floating-point format (double precision)
cvtf.ls	Conversion to floating-point format (single precision)
cvtf.sd	Conversion to floating-point format (double precision)
cvtf.sh	Conversion to half-precision floating-point format (single precision)
cvtf.sl	Conversion to fixed-point format (single precision)
cvtf.sul	Conversion to unsigned fixed-point format (single precision)
cvtf.suw	Conversion to unsigned fixed-point format (single precision)
cvtf.sw	Conversion to fixed-point format (single precision)
cvtf.uld	Conversion to floating-point format (double precision)
cvtf.uls	Conversion to floating-point format (single precision)
cvtf.uwd	Conversion to floating-point format (double precision)
cvtf.uws	Conversion to floating-point format (single precision)
cvtf.wd	Conversion to floating-point format (double precision)
cvtf.ws	Conversion to floating-point format (single precision)
floorf.dl	Conversion to fixed-point format (double precision)
floorf.dw	Conversion to fixed-point format (double precision)
floorf.dul	Conversion to unsigned fixed-point format (double precision)
floorf.duw	Conversion to unsigned fixed-point format (double precision)
floorf.sl	Conversion to fixed-point format (single precision)
floorf.sw	Conversion to fixed-point format (single precision)
floorf.sul	Conversion to unsigned fixed-point format (single precision)
floorf.suw	Conversion to unsigned fixed-point format (single precision)

Instruction	Meanings
trncf.dl	Conversion to fixed-point format (double precision)
trncf.dul	Conversion to unsigned fixed-point format (double precision)
trncf.duw	Conversion to unsigned fixed-point format (double precision)
trncf.dw	Conversion to fixed-point format (double precision)
trncf.sl	Conversion to fixed-point format (single precision)
trncf.sul	Conversion to unsigned fixed-point format (single precision)
trncf.suw	Conversion to unsigned fixed-point format (single precision)
trncf.sw	Conversion to fixed-point format (single precision)

Table 4-47. Floating-point Operation Instructions (Compare Instructions)

Instruction	Meanings
cmpf.d	Floating-point compare (double)
cmpf.s	Floating-point compare (single)

Table 4-48. Floating-point Operation Instructions (Conditional Move Instructions)

Instruction	Meanings
cmovf.d	Conditional move (double precision)
cmovf.s	Conditional move (single precision)

Table 4-49. Floating-point Operation Instructions (Conditional Bit Move Instructions)

Instruction	Meanings
trfsr	Flag transfer

absf.d

Floating-point absolute value (double precision) (Floating-point Absolute Value (Double))

[Syntax]

- absf.d reg1, reg2

[Function]

This instruction takes the absolute value from the double-precision floating-point format contents of the register pair specified by general-purpose register reg1, and stores it in the register pair specified by general-purpose register reg2.

[Description]

- The assembler generates one absf.d machine instruction.

absf.s

Floating-point absolute value (single precision) (Floating-point Absolute Value (Single))

[Syntax]

- absf.s reg1, reg2

[Function]

This instruction takes the absolute value from the single-precision floating-point format contents of general-purpose register reg1, and stores it in general-purpose register reg2.

[Description]

- The assembler generates one absf.s machine instruction.

addf.d

Floating-point add (double precision) (Floating-point Add (Double))

[Syntax]

- addf.d reg1, reg2, reg3

[Function]

This instruction adds the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 with the double-precision floating-point format contents of the register pair specified by general-purpose register reg2, and stores the result in the register pair specified by general-purpose register reg3. The operation is executed as if it were of infinite accuracy, and the result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one addf.d machine instruction.

addf.s

Floating-point add (single precision) (Floating-point Add (Single))

[Syntax]

- addf.s reg1, reg2, reg3

[Function]

This instruction adds the single-precision floating-point format contents of general-purpose register reg1 with the single-precision floating-point format contents of general-purpose register reg2, and stores the result in general-purpose register reg3. The operation is executed as if it were of infinite accuracy, and the result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one addf.s machine instruction.

divf.d

Floating-point division (double precision) (Floating-point Divide (Double))

[Syntax]

- divf.d reg1, reg2, reg3

[Function]

This instruction divides double-precision floating-point format contents of the register pair specified by general-purpose register reg2 by the double-precision floating-point format contents of the register pair specified by general-purpose register reg1, and stores the result in the register pair specified by general-purpose register reg3. The operation is executed as if it were of infinite accuracy, and the result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one divf.d machine instruction.

divf.s

Floating-point division (single precision) (Floating-point Divide (Single))

[Syntax]

- divf.s reg1, reg2, reg3

[Function]

This instruction divides the single-precision floating-point format contents of general-purpose register reg2 by the single-precision floating-point format contents of general-purpose register reg1, and stores the result in general-purpose register reg3. The operation is executed as if it were of infinite accuracy, and the result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one divf.s machine instruction.

maxf.d

Floating-point maximum value (double precision) (Floating-point Maximum (Double))

[Syntax]

- maxf.d reg1, reg2, reg3

[Function]

This instruction extracts the maximum value from the double-precision floating-point format data in the register pair specified by general-purpose registers reg1 and reg2, and stores it in the register pair specified by general-purpose register reg3.

If one of the source operands is S-NaN, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, Q-NaN is stored and no exception occurs.

[Description]

- The assembler generates one maxf.d machine instruction.

maxf.s

Floating-point maximum value (single precision) (Floating-point Maximum (Single))

[Syntax]

- maxf.s reg1, reg2, reg3

[Function]

This instruction extracts the maximum value from the single-precision floating-point format data in general-purpose registers reg1 and reg2, and stores it in general-purpose register reg3.

If one of the source operands is S-NaN, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, Q-NaN is stored and no exception occurs.

[Description]

- The assembler generates one maxf.s machine instruction.

minf.d

Floating-point minimum value (double precision) (Floating-point Minimum (Double))

[Syntax]

- minf.d reg1, reg2, reg3

[Function]

This instruction extracts the minimum value from the double-precision floating-point format data in the register pair specified by general-purpose registers reg1 and reg2, and stores it in the register pair specified by general-purpose register reg3.

If one of the source operands is S-NaN, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, Q-NaN is stored and no exception occurs.

[Description]

- The assembler generates one minf.d machine instruction.

minf.s

Floating-point minimum value (single precision) (Floating-point Minimum (Single))

[Syntax]

- minf.s reg1, reg2, reg3

[Function]

This instruction extracts the minimum value from the single-precision floating-point format data in general-purpose registers reg1 and reg2, and stores it in general-purpose register reg3.

If one of the source operands is S-NaN, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, Q-NaN is stored and no exception occurs.

[Description]

- The assembler generates one minf.s machine instruction.

mulf.d

Floating-point multiplication (double precision) (Floating-point Multiply (Double))

[Syntax]

- mulf.d reg1, reg2, reg3

[Function]

This instruction multiplies double-precision floating-point format contents of the register pair specified by general-purpose register reg2 by the double-precision floating-point format contents of the register pair specified by general-purpose register reg1, and stores the result in general-purpose register reg3.

[Description]

- The assembler generates one mulf.d machine instruction.

mulf.s

Floating-point multiplication (single precision) (Floating-point Multiply (Single))

[Syntax]

- mulf.s reg1, reg2, reg3

[Function]

This instruction multiplies the single-precision floating-point format contents of general-purpose register reg2 by the single-precision floating-point format contents of general-purpose register reg1, and stores the result in general-purpose register reg3.

[Description]

- The assembler generates one mulf.s machine instruction.

negf.d

Floating-point sign inversion (double precision) (Floating-point Negate (Double))

[Syntax]

- negf.d reg1, reg2

[Function]

This instruction inverts the sign of double-precision floating-point format contents of the register pair specified by general-purpose register reg1, and stores the result in general-purpose register reg2.

[Description]

- The assembler generates one negf.d machine instruction.

negf.s

Floating-point sign inversion (single precision) (Floating-point Negate (Single))

[Syntax]

- negf.s reg1, reg2

[Function]

This instruction inverts the sign of the single-precision floating-point format contents of general-purpose register reg1, and stores the result in general-purpose register reg2.

[Description]

- The assembler generates one negf.s machine instruction.

recipf.d

Reciprocal (double precision) (Reciprocal of a Floating-point Value (Double))

[Syntax]

- recipf.d reg1, reg2

[Function]

This instruction approximates the reciprocal of the double-precision floating-point format contents of the register pair specified by general-purpose register reg1, and stores the result in the register pair specified by general-purpose register reg2. The result differs from the result obtained by using the divf instruction.

[Description]

- The assembler generates one recipf.d machine instruction.

recipf.s

Reciprocal (single precision) (Reciprocal of a Floating-point Value (Single))

[Syntax]

- recipf.s reg1, reg2

[Function]

This instruction approximates the reciprocal of the single-precision floating-point format contents of general-purpose register reg1, and stores the result in general-purpose register reg2. The result differs from the result obtained by using the divf instruction.

[Description]

- The assembler generates one recipf.s machine instruction.

rsqrtf.d

Reciprocal of square root (double precision) (Reciprocal of the Square Root of a Floating-point Value (Double))

[Syntax]

- rsqrtf.d reg1, reg2

[Function]

This instruction obtains the arithmetic positive square root of the double-precision floating-point format contents of the register pair specified by general-purpose register reg1, then approximates the reciprocal of this result and stores the result in the register pair specified by general-purpose register reg2.

The result differs from the result obtained when using a combination of the sqrtf and divf instructions.

[Description]

- The assembler generates one rsqrtf.d machine instruction.

rsqrtf.s

Reciprocal of square root (single precision) (Reciprocal of the Square Root of a Floating-point Value (Single))

[Syntax]

- rsqrtf.s reg1, reg2

[Function]

This instruction obtains the arithmetic positive square root of the single-precision floating-point format contents of general-purpose register reg1, then approximates the reciprocal of this result and stores it in general-purpose register reg2.

The result differs from the result obtained when using a combination of the sqrtf and divf instructions.

[Description]

- The assembler generates one rsqrtf.s machine instruction.

sqrtf.d

Square root (double precision) (Floating-point Square Root (Double))

[Syntax]

- sqrtf.d reg1, reg2

[Function]

This instruction obtains the arithmetic positive square root of the double-precision floating-point format contents of the register pair specified by general-purpose register reg1, and stores the result in the register pair specified by general-purpose register reg2. The operation is executed as if it were of infinite accuracy, and the result is rounded in accordance with the current rounding mode. When the source operand value is -0, the result becomes -0.

[Description]

- The assembler generates one sqrtf.d machine instruction.

sqrtf.s

Square root (single precision) (Floating-point Square Root (Single))

[Syntax]

- sqrtf.s reg1, reg2

[Function]

This instruction obtains the arithmetic positive square root of the single-precision floating-point format contents of general-purpose register reg1, and stores it in general-purpose register reg2. The operation is executed as if it were of infinite accuracy, and the result is rounded in accordance with the current rounding mode. When the source operand value is -0, the result becomes -0.

[Description]

- The assembler generates one sqrtf.s machine instruction.

subf.d

Floating-point subtraction (double precision) (Floating-point Subtract (Double))

[Syntax]

- subf.d reg1, reg2, reg3

[Function]

This instruction subtracts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 from the double-precision floating-point format contents of the register pair specified by general-purpose register reg2, and stores the result in the register pair specified by general-purpose register reg3. The operation is executed as if it were of infinite accuracy, and the result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one subf.d machine instruction.

subf.s

Floating-point subtraction (single precision) (Floating-point Subtract (Single))

[Syntax]

- subf.s reg1, reg2, reg3

[Function]

This instruction subtracts the single-precision floating-point format contents of general-purpose register reg1 from the single-precision floating-point format contents of general-purpose register reg2, and stores the result in general-purpose register reg3. The operation is executed as if it were of infinite accuracy, and the result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one subf.s machine instruction.

fmaf.s

Floating-point fused-multiply-add operation (single precision) (Floating-point Fused-Multiply-add (Single))

[Syntax]

- fmaf.s reg1, reg2, reg3

[Function]

This instruction multiplies the single-precision floating-point format contents in general-purpose register reg2 with the single-precision floating-point format contents in general-purpose register reg1, adds the single-precision floating-point format contents in general-purpose register reg3, and stores the result in general-purpose register reg3. The operation is executed as if it were of infinite accuracy. The result of the multiply operation is not rounded, but the result of the add operation is rounded, in accordance with the current rounding mode.

[Description]

- The assembler generates one fmaf.s machine instruction.

fmsf.s

Floating-point fused-multiply-subtract operation (single precision) (Floating-point Fused-Multiply-subtract (Single))

[Syntax]

- fmsf.s reg1, reg2, reg3

[Function]

This instruction multiplies the single-precision floating-point format contents in general-purpose register reg2 with the single-precision floating-point format contents in general-purpose register reg1, subtracts the single-precision floating-point format contents in general-purpose register reg3, and stores the result in general-purpose register reg3. The operation is executed as if it were of infinite accuracy. The result of the multiply operation is not rounded, but the result of the subtract operation is rounded, in accordance with the current rounding mode.

[Description]

- The assembler generates one fmsf.s machine instruction.

fnmaf.s

Floating-point fused-multiply-add operation (single precision) (Floating-point Fused-Negate-Multiply-add (Single))

[Syntax]

- fnmaf.s reg1, reg2, reg3

[Function]

This instruction multiplies the single-precision floating-point format contents in general-purpose register reg2 with the single-precision floating-point format contents in general-purpose register reg1, adds the single-precision floating-point format contents in general-purpose register reg3, inverts the sign, and stores the result in general-purpose register reg3. The operation is executed as if it were of infinite accuracy. The result of the multiply operation is not rounded, but the result of the add operation is rounded, in accordance with the current rounding mode.

[Description]

- The assembler generates one fnmaf.s machine instruction.

fnmsf.s

Floating-point fused-multiply-add operation (single precision) (Floating-point Fused-Negate-Multiply-subtrat (Single))

[Syntax]

- fnmsf.s reg1, reg2, reg3

[Function]

This instruction multiplies the single-precision floating-point format contents in general-purpose register reg2 with the single-precision floating-point format contents in general-purpose register reg1, subtracts the single-precision floating-point format contents in general-purpose register reg3, inverts the sign, and stores the result in general-purpose register reg3. The operation is executed as if it were of infinite accuracy. The result of the multiply operation is not rounded, but the result of the subtract operation is rounded, in accordance with the current rounding mode.

[Description]

- The assembler generates one fnmsf.s machine instruction.

ceilf.dl

Conversion to fixed-point format (double precision) (Floating-point Convert Double to Long, round toward positive (Double))

[Syntax]

- ceilf.dl reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the +∞ direction regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{63} - 1$ to -2^{63}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{63} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{63} is returned.

[Description]

- The assembler generates one ceilf.dl machine instruction.

ceilf.dw

Conversion to fixed-point format (double precision) (Floating-point Convert Double to Word, round toward positive (Double))

[Syntax]

- ceilf.dw reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the +∞ direction regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{31} - 1$ to -2^{31}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{31} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{31} is returned.

[Description]

- The assembler generates one ceilf.dw machine instruction.

ceilf.dul

Conversion to unsigned fixed-point format (double precision) (Floating-point Convert Double to Unsigned-Long, round toward positive (Double))

[Syntax]

- ceilf.dul reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to unsigned 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the +∞ direction regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{64} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{64} - 1 to 0,

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{64} - 1 to 0, or +∞ : 2^{64} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one ceilf.dul machine instruction.

ceilf.duw

Conversion to unsigned fixed-point format (double precision) (Floating-point Convert Double to Unsigned-Word, round toward positive (Double))

[Syntax]

- ceilf.duw reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to unsigned 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the +∞ direction regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{32} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{32} - 1 to 0, or +∞ : 2^{32} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one ceilf.duw machine instruction.

ceilf.sl

Conversion to fixed-point format (single precision) (Floating-point Convert Single to Long, round toward positive (Single))

[Syntax]

- ceilf.sl reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the +∞ direction regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{63} - 1$ to -2^{63}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{63} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{63} is returned.

[Description]

- The assembler generates one ceilf.sl machine instruction.

ceilf.sw

Conversion to fixed-point format (single precision) (Floating-point Convert Single to Word, round toward positive (Single))

[Syntax]

- ceilf.sw reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the +∞ direction regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{31} - 1$ to -2^{31}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{31} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{31} is returned.

[Description]

- The assembler generates one ceilf.sw machine instruction.

ceilf.sul

Conversion to unsigned fixed-point format (single precision) (Floating-point Convert Single to Unsigned-Long, round toward positive (Single))

[Syntax]

- ceilf.sul reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents specified by general-purpose register reg1 to unsigned 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the +∞ direction regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{64} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{64} - 1 to 0, or +∞ : 2^{64} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one ceilf.sul machine instruction.

ceilf.suw

Conversion to unsigned fixed-point format (single precision) (Floating-point Convert Single to Unsigned-Word, round toward positive (Single))

[Syntax]

- ceilf.suw reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of the register pair specified by general-purpose register reg1 to unsigned 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the +∞ direction regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{32} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{32} - 1 to 0, or +∞ : 2^{32} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one ceilf.suw machine instruction.

cvtf.dl

Conversion to fixed-point format (double precision) (Floating-point Convert Double to Long (Double))

[Syntax]

- cvtf.dl reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to 64-bit fixed-point format, in accordance with the current rounding mode, and stores the result in the register pair specified by general-purpose register reg2.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{63} - 1$ to -2^{63}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{63} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{63} is returned.

[Description]

- The assembler generates one cvtf.dl machine instruction.

cvtf.ds

Conversion to floating-point format (double precision) (Floating-point Convert Double to Single (Double))

[Syntax]

- cvtf.ds reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to single-precision floating-point format, and stores the result in general-purpose register reg2. The result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one cvtf.ds machine instruction.

cvtf.dul

Conversion to unsigned fixed-point format (double precision) (Floating-point Convert Double to Unsigned-Long (Double))

[Syntax]

- cvtf.dul reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to unsigned 64-bit fixed-point format, in accordance with the current rounding mode, and stores the result in the register pair specified by general-purpose register reg2.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{64} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{64} - 1 to 0, or +∞ : 2^{64} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one cvtf.dul machine instruction.

cvtf.duw

Conversion to unsigned fixed-point format (double precision) (Floating-point Convert Double to Unsigned-Word (Double))

[Syntax]

- cvtf.duw reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to unsigned 32-bit fixed-point format, and stores the result in general-purpose register reg2.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{32} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{32} - 1 to 0, or +∞ : 2^{32} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one cvtf.duw machine instruction.

cvtf.dw

Conversion to fixed-point format (double precision) (Floating-point Convert Double to Word (Double))

[Syntax]

- cvtf.dw reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to 32-bit fixed-point format, and stores the result in general-purpose register reg2.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{31} - 1$ to -2^{31}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{31} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{31} is returned.

[Description]

- The assembler generates one cvtf.dw machine instruction.

cvtf.hs

Conversion to floating-point format (single precision) (Floating-point Convert Single to Half(Single))

[Syntax]

- cvtf.hs reg1, reg2

[Function]

This instruction arithmetically converts the half-precision floating-point format contents in the lower 16 bits of general-purpose register reg2 to single-precision floating-point format, rounding the result in accordance with the current rounding mode, and stores the result in general-purpose register reg3.

[Description]

- The assembler generates one cvtf.hs machine instruction.

cvtf.ld

Conversion to floating-point format (double precision) (Floating-point Convert Long to Double (Double))

[Syntax]

- cvtf.ld reg1, reg2

[Function]

This instruction arithmetically converts the 64-bit fixed-point format contents of the register pair specified by general-purpose register reg1 to double-precision floating-point format in accordance with the current rounding mode, and stores the result in the register pair specified by general-purpose register reg2.

[Description]

- The assembler generates one cvtf.ld machine instruction.

cvtf.ls

Conversion to floating-point format (single precision) (Floating-point Convert Long to Single (Single))

[Syntax]

- cvtf.ls reg1, reg2

[Function]

This instruction arithmetically converts the 64-bit fixed-point format contents of the register pair specified by general-purpose register reg1 to single-precision floating-point format, and stores the result in general-purpose register reg2. The result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one cvtf.ls machine instruction.

cvtf.sd

Conversion to floating-point format (double precision) (Floating-point Convert Single to Double (Double))

[Syntax]

- cvtf.sd reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to double-precision floating-point format, in accordance with the current rounding mode, and stores the result in the register pair specified by general-purpose register reg2.

[Description]

- The assembler generates one cvtf.sd machine instruction.

cvtf.sh

Conversion to half-precision floating-point format (single precision) (Floating-point Convert Single to Half (Single))

[Syntax]

- cvtf.sh reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents in general-purpose register reg2 to half-precision floating-point format, rounding the result in accordance with the current rounding mode. The result is zero-extended to word length and stored in general-purpose register reg3.

[Description]

- The assembler generates one cvtf.ss machine instruction.

cvtf.sl

Conversion to fixed-point format (single precision) (Floating-point Convert Single to Long (Single))

[Syntax]

- cvtf.sl reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to 64-bit fixed-point format, in accordance with the current rounding mode, and stores the result in the register pair specified by general-purpose register reg2.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{63} - 1$ to -2^{63}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{63} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{63} is returned.

[Description]

- The assembler generates one cvtf.sl machine instruction.

cvtf.sul

Conversion to unsigned fixed-point format (single precision) (Floating-point Convert Single to Unsigned-Long (Single))

[Syntax]

- cvtf.sul reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to unsigned 64-bit fixed-point format, in accordance with the current rounding mode, and stores the result in the register pair specified by general-purpose register reg2.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{64} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{64} - 1 to 0, or +∞ : 2^{64} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one cvtf.sul machine instruction.

cvtf.suw

Conversion to unsigned fixed-point format (single precision) (Floating-point Convert Single to Unsigned-Word (Single))

[Syntax]

- cvtf.suw reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to unsigned 32-bit fixed-point format, and stores the result in general-purpose register reg2.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{32} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{32} - 1 to 0, or +∞ : 2^{32} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one cvtf.suw machine instruction.

cvtf.sw

Conversion to fixed-point format (single precision) (Floating-point Convert Single to Word (Single))

[Syntax]

- cvtf.sw reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to 32-bit fixed-point format, and stores the result in general-purpose register reg2.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{31} - 1$ to -2^{31}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{31} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{31} is returned.

[Description]

- The assembler generates one cvtf.sw machine instruction.

cvtf.uld

Conversion to floating-point format (double precision) (Floating-point Convert Unsigned-Long to Double (Double))

[Syntax]

- cvtf.uld reg1, reg2

[Function]

This instruction arithmetically converts the unsigned 64-bit fixed-point format contents of the register pair specified by general-purpose register reg1 to double-precision floating-point format in accordance with the current rounding mode, and stores the result in the register pair specified by general-purpose register reg2.

[Description]

- The assembler generates one cvtf.uld machine instruction.

cvtf.uls

Conversion to floating-point format (single precision) (Floating-point Convert Unsigned-Long to Single (Single))

[Syntax]

- cvtf.uls reg1, reg2

[Function]

This instruction arithmetically converts the unsigned 64-bit fixed-point format contents of the register pair specified by general-purpose register reg1 to single-precision floating-point format, and stores the result in general-purpose register reg2. The result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one cvtf.uls machine instruction.

cvtf.uwd

Conversion to floating-point format (double precision) (Floating-point Convert Unsigned-Word to Double (Double))

[Syntax]

- cvtf.uwd reg1, reg2

[Function]

This instruction arithmetically converts the unsigned 32-bit fixed-point format contents of general-purpose register reg1 to double-precision floating-point format, in accordance with the current rounding mode, and stores the result in the register pair specified by general-purpose register reg2.

This conversion operation is performed accurately, without any loss of precision.

[Description]

- The assembler generates one cvtf.uwd machine instruction.

cvtf.uws

Conversion to floating-point format (single precision) (Floating-point Convert Unsigned-Word to Single (Single))

[Syntax]

- cvtf.uws reg1, reg2

[Function]

This instruction arithmetically converts the unsigned 32-bit fixed-point format contents of general-purpose register reg1 to single-precision floating-point format, and stores the result in general-purpose register reg2. The result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one cvtf.uws machine instruction.

cvtf.wd

Conversion to floating-point format (double precision) (Floating-point Convert Word to Double (Double))

[Syntax]

- cvtf.wd reg1, reg2

[Function]

This instruction arithmetically converts the 32-bit fixed-point format contents of general-purpose register reg1 to double-precision floating-point format, in accordance with the current rounding mode, and stores the result in the register pair specified by general-purpose register reg2.

This conversion operation is performed accurately, without any loss of precision.

[Description]

- The assembler generates one cvtf.wd machine instruction.

cvtf.ws

Conversion to floating-point format (single precision) (Floating-point Convert Word to Single (single))

[Syntax]

- cvtf.ws reg1, reg2

[Function]

This instruction arithmetically converts the 32-bit fixed-point format contents of general-purpose register reg1 to single-precision floating-point format, and stores the result in general-purpose register reg2. The result is rounded in accordance with the current rounding mode.

[Description]

- The assembler generates one cvtf.ws machine instruction.

floorf.dl

Conversion to fixed-point format (double precision) (Floating-point Convert Double to Long, round toward negative (Double))

[Syntax]

- floorf.dl reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the -∞ direction, regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{63} - 1$ to -2^{63}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{63} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{63} is returned.

[Description]

- The assembler generates one floorf.dl machine instruction.

floorf.dw

Conversion to fixed-point format (double precision) (Floating-point Convert Double to Word, round toward negative (Double))

[Syntax]

- floorf.dw reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the -∞ direction, regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{31} - 1$ to -2^{31}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{31} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{31} is returned.

[Description]

- The assembler generates one floorf.dw machine instruction.

floorf.dul

Conversion to unsigned fixed-point format (double precision) (Floating-point Convert Double to Unsigned-Long, round toward negative (Double))

[Syntax]

- floorf.dul reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to unsigned 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the -∞ direction, regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{64} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{64} - 1 to 0, or +∞ : 2^{64} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one floorf.dul machine instruction.

floorf.duw

Conversion to unsigned fixed-point format (double precision) (Floating-point Convert Double to Unsigned-Word, round toward negative (Double))

[Syntax]

- floorf.duw reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to unsigned 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the -∞ direction, regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{32} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{32} - 1 to 0, or +∞ : 2^{32} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one floorf.duw machine instruction.

floorf.sl

Conversion to fixed-point format (single precision) (Floating-point Convert Double to Long, round toward negative (Single))

[Syntax]

- floorf.sl reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the -∞ direction, regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{63} - 1$ to -2^{63}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{63} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{63} is returned.

[Description]

- The assembler generates one floorf.sl machine instruction.

floorf.sw

Conversion to fixed-point format (single precision) (Floating-point Convert Single to Word, round toward negative (Single))

[Syntax]

- floorf.sw reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the -∞ direction, regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{31} - 1$ to -2^{31}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{31} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{31} is returned.

[Description]

- The assembler generates one floorf.sw machine instruction.

floorf.sul

Conversion to unsigned fixed-point format (single precision) (Floating-point Convert Single to Unsigned-Long, round toward negative (Single))

[Syntax]

- floorf.sul reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to unsigned 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the -∞ direction, regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{64} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{64} - 1 to 0, or +∞ : 2^{64} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one floorf.sul machine instruction.

floorf.suw

Conversion to unsigned fixed-point format (single precision) (Floating-point Convert Single to Unsigned-Word, round toward negative (Single))

[Syntax]

- floorf.suw reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to unsigned 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the -∞ direction, regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{32} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{32} - 1 to 0, or +∞ : 2^{32} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one floorf.suw machine instruction.

trncf.dl

Conversion to fixed-point format (double precision) (Floating-point Convert Double to Long, round toward zero (Double))

[Syntax]

- trncf.dl reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the zero direction, regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{63} - 1$ to -2^{63}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{63} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{63} is returned.

[Description]

- The assembler generates one trncf.dl machine instruction.

trncf.dul

Conversion to unsigned fixed-point format (double precision) (Floating-point Convert Double to Unsigned-Long, round toward zero (Double))

[Syntax]

- trncf.dul reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to unsigned 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the zero direction, regardless of the current rounding mode.

The result is rounded in the zero direction, regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{64} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{64} - 1 to 0, or +∞ : 2^{64} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one trncf.dul machine instruction.

trncf.duw

Conversion to unsigned fixed-point format (double precision) (Floating-point Convert Double to Unsigned-Word, round toward zero (Double))

[Syntax]

- trncf.duw reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to unsigned 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the zero direction, regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{32} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{32} - 1 to 0, or +∞ : 2^{32} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one trncf.duw machine instruction.

trncf.dw

Conversion to fixed-point format (double precision) (Floating-point Convert Double to Word, round toward zero (Double))

[Syntax]

- trncf.dw reg1, reg2

[Function]

This instruction arithmetically converts the double-precision floating-point format contents of the register pair specified by general-purpose register reg1 to 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the zero direction, regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{31} - 1$ to -2^{31}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{31} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{31} is returned.

[Description]

- The assembler generates one trncf.dw machine instruction.

trncf.sl

Conversion to fixed-point format (single precision) (Floating-point Convert Single to Long, round toward zero (Single))

[Syntax]

- trncf.sl reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the zero direction, regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{63} - 1$ to -2^{63}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{63} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{63} is returned.

[Description]

- The assembler generates one trncf.sl machine instruction.

trncf.sul

Conversion to unsigned fixed-point format (single precision) (Floating-point Convert Single to Unsigned-Long, round toward zero (Single))

[Syntax]

- trncf.sul reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point format contents of general-purpose register reg1 to unsigned 64-bit fixed-point format, and stores the result in the register pair specified by general-purpose register reg2.

The result is rounded in the zero direction, regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{64} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{64} - 1 to 0, or +∞ : 2^{64} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one trncf.sul machine instruction.

trncf.suw

Conversion to unsigned fixed-point format (single precision) (Floating-point Convert Single to Unsigned-Word, round toward zero (Single))

[Syntax]

- trncf.suw reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point number format contents of general-purpose register reg1 to unsigned 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the zero direction, regardless of the current rounding mode.

When the source operand is infinite, not-a-number, or negative number, or when the rounded result is outside the range of 2^{32} - 1 to 0, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number outside the range of 2^{32} - 1 to 0, or +∞ : 2^{32} - 1 is returned.
- Source is a negative number, not-a-number, or -∞ : 0 is returned.

[Description]

- The assembler generates one trncf.suw machine instruction.

trncf.sw

Conversion to fixed-point format (single precision) (Floating-point Convert Single to Word, round toward zero (Single))

[Syntax]

- trncf.sw reg1, reg2

[Function]

This instruction arithmetically converts the single-precision floating-point number format contents of general-purpose register reg1 to 32-bit fixed-point format, and stores the result in general-purpose register reg2.

The result is rounded in the zero direction, regardless of the current rounding mode.

When the source operand is infinite or not-a-number, or when the rounded result is outside the range of $2^{31} - 1$ to -2^{31}, an IEEE754-defined invalid operation exception is detected.

If invalid operation exceptions are not enabled, the preservation bit (bit 4) of the FPSR register is set as an invalid operation and no exception occurs. The return value differs as follows, according to differences among sources.

- Source is a positive number or +∞ : $2^{31} - 1$ is returned.
- Source is a negative number, not-a-number, or -∞ : -2^{31} is returned.

[Description]

- The assembler generates one trncf.sw machine instruction.

cmpf.d

Floating-point compare (double)

[Syntax]

- cmpf.d imm4, reg1, reg2, cc#3
- cmpf*cnd*.d reg1, reg2

The following can be specified for imm4:

- Absolute expression having a value up to 4 bits

[Function]

- Syntax "cmpf.d imm4, reg1, reg2, cc#3"
  The content in double-precision floating-point format in the register pair specified by reg2 is compared with the content in double-precision floating-point format in the register pair specified by reg1, via the imm4 comparison condition. The result (1 if true; 0 if false) is set in the condition bit (CC(7:0) bits; bits 31-24) in the FPSR register specified via cc#3. If cc#3 is omitted, it is set in the CC0 bit (bit 24).
- Syntax "cmpf*cnd*.d reg1, reg2"
  Via cmpf*cnd*.d, a corresponding "cmpf.d" instruction is generated (see "Table 4-50. cmpfcnd.d Instruction List" for details), and expanded in the format "cmpf.d imm4, reg1, reg2, cc#3". The content in single-precision floating-point format in the register pair specified by reg2 is compared with the content in single-precision floating-point format in the register pair specified by reg1, via the comparison condition. The result (1 if true; 0 if false) is set in the condition bit (CC(7:0) bits; bits 31-24) in the FPSR register specified via cc#3. If cc#3 is omitted, it is set in the CC0 bit (bit 24).

[Description]

- If the instruction is executed in syntax "cmpf.d imm4, reg1, reg2, cc#3", the assembler generates one cmpf.d machine instruction.
- If the instruction is executed in syntax "cmpf*cnd*.d reg1, reg2", the assembler generates the corresponding cmpf.d instruction (see "Table 4-50. cmpfcnd.d Instruction List") and expands it to syntax "cmpf.d imm4, reg1, reg2, cc#3".

Table 4-50. cmpf*cnd*.d Instruction List

Instruction	Condition	Meaning of Condition	Instruction Expansion
cmpff.d	FALSE	Always false	cmpf.d 0x0
cmpfun.d	Unordered	At least one of reg1 and reg2 is a non-number	cmpf.d 0x1
cmpfeq.d	reg2 = reg1	Neither is a non-number, and they are equal	cmpf.d 0x2
cmpfueq.d	reg2 ?= reg1	At least one is a non-number, or they are equal	cmpf.d 0x3
cmpfolt.d	reg2 < reg1	Neither is a non-number, and less than	cmpf.d 0x4
cmpfult.d	reg2 ?< reg1	At least one is a non-number, or less than	cmpf.d 0x5
cmpfole.d	reg2 <= reg1	Neither is a non-number, and less than or equal	cmpf.d 0x6
cmpfule.d	reg2 ?<= reg1	At least one is a non-number, or less than or equal	cmpf.d 0x7
cmpfsf.d	FALSE	Always false	cmpf.d 0x8
cmpfngle.d	Unordered	At least one of reg1 and reg2 is a non-number	cmpf.d 0x9

Instruction	Condition	Meaning of Condition	Instruction Expansion
cmpfseq.d	reg2 = reg1	Neither is a non-number, and they are equal	cmpf.d 0xA
cmpfngl.d	reg2 ?= reg1	At least one is a non-number, or they are equal	cmpf.d 0xB
cmpflt.d	reg2 < reg1	Neither is a non-number, and less than	cmpf.d 0xC
cmpfnge.d	reg2 ?< reg1	At least one is a non-number, or less than	cmpf.d 0xD
cmpfle.d	reg2 <= reg1	Neither is a non-number, and less than or equal	cmpf.d 0xE
cmpfngt.d	reg2 ?<= reg1	At least one is a non-number, or less than or equal	cmpf.d 0xF

Remark ?: Unordered

[Caution]

- If an absolute expression having a value exceeding 4 bits is specified as imm4 of the cmpf.d instruction, the following message is output, and assembly continues using the lower 4 bits of the specified value.

```
W0550011 : illegal operand (range error in immediate).
```

cmpf.s

Floating-point compare (single)

[Syntax]

- cmpf.s imm4, reg1, reg2, cc#3
- cmpf*cnd*.s reg1, reg2

The following can be specified for imm4:

- Absolute expression having a value up to 4 bits

[Function]

- Syntax "cmpf.s imm4, reg1, reg2, cc#3"
  The content in single-precision floating-point format in the register pair specified by reg2 is compared with the content in single-precision floating-point format in the register pair specified by reg1, via the imm4 comparison condition. The result (1 if true; 0 if false) is set in the condition bit (CC(7:0) bits; bits 31-24) in the FPSR register specified via cc#3. If cc#3 is omitted, it is set in the CC0 bit (bit 24).
- Syntax "cmpf*cnd*.s reg1, reg2"
  Via cmpf*cnd*.s, a corresponding "cmpf.s" instruction is generated (see "Table 4-51. cmpfcnd.s Instruction List" for details), and expanded in the format "cmpf.s imm4, reg1, reg2, cc#3". The content in single-precision floating-point format in the register pair specified by reg2 is compared with the content in single-precision floating-point format in the register pair specified by reg1, via the comparison condition. The result (1 if true; 0 if false) is set in the condition bit (CC(7:0) bits; bits 31-24) in the FPSR register specified via cc#3. If cc#3 is omitted, it is set in the CC0 bit (bit 24).

[Description]

- If the instruction is executed in syntax "cmpf.s imm4, reg1, reg2, cc#3", the assembler generates one cmpf.s machine instruction.
- If the instruction is executed in syntax "cmpf*cnd*.s reg1, reg2", the assembler generates the corresponding cmpf.s instruction (see "Table 4-51. cmpfcnd.s Instruction List") and expands it to syntax "cmpf.s imm4, reg1, reg2, cc#3".

Table 4-51. cmpf*cnd*.s Instruction List

Instruction	Condition	Meaning of Condition	Instruction Expansion
cmpff.s	FALSE	Always false	cmpf.s 0x0
cmpfun.s	Unordered	At least one of reg1 and reg2 is a non-number	cmpf.s 0x1
cmpfeq.s	reg2 = reg1	Neither is a non-number, and they are equal	cmpf.s 0x2
cmpfueq.s	reg2 ?= reg1	At least one is a non-number, or they are equal	cmpf.s 0x3
cmpfolt.s	reg2 < reg1	Neither is a non-number, and less than	cmpf.s 0x4
cmpfult.s	reg2 ?< reg1	At least one is a non-number, or less than	cmpf.s 0x5
cmpfole.s	reg2 <= reg1	Neither is a non-number, and less than or equal	cmpf.s 0x6
cmpfule.s	reg2 ?<= reg1	At least one is a non-number, or less than or equal	cmpf.s 0x7
cmpfsf.s	FALSE	Always false	cmpf.s 0x8
cmpfngle.s	Unordered	At least one of reg1 and reg2 is a non-number	cmpf.s 0x9

Instruction	Condition	Meaning of Condition	Instruction Expansion
cmpfseq.s	reg2 = reg1	Neither is a non-number, and they are equal	cmpf.s 0xA
cmpfngl.s	reg2 ?= reg1	At least one is a non-number, or they are equal	cmpf.s 0xB
cmpflt.s	reg2 < reg1	Neither is a non-number, and less than	cmpf.s 0xC
cmpfnge.s	reg2 ?< reg1	At least one is a non-number, or less than	cmpf.s 0xD
cmpfle.s	reg2 <= reg1	Neither is a non-number, and less than or equal	cmpf.s 0xE
cmpfngt.s	reg2 ?<= reg1	At least one is a non-number, or less than or equal	cmpf.s 0xF

Remark ?: Unordered

[Caution]

- If an absolute expression having a value exceeding 4 bits is specified as imm4 of the cmpf.s instruction, the following message is output, and assembly continues using the lower 4 bits of the specified value.

```
W0550011 : illegal operand (range error in immediate).
```

cmovf.d

Conditional move (double precision) (Floating-point Conditional Move (Double))

[Syntax]

- cmovf.d cc#3, reg1, reg2, reg3

[Function]

When the CC(7:0) bits of the FPSR register specified by fcbit in the opcode are true (1), data from the register pair specified by reg1 is stored in the register pair specified by reg3. When these bits are false (0), data from the register pair specified by reg2 is stored in the register pair specified by reg3.

[Description]

- The assembler generates one cmovf.d machine instruction.

[Caution]

- If r0 is specified as reg3 in the cmovf.d instruction, the assembler outputs the following message and stops assembling.

```
E0550262 : Illegal operand (cannot use r0 as destination in RH850 mode).
```

cmovf.s

Conditional move (single precision) (Floating-point Conditional Move (Single))

[Syntax]

- cmovf.s cc#3, reg1, reg2, reg3

[Function]

When the CC(7:0) bits of the FPSR register specified by fcbit in the opcode are true (1), data from reg1 is stored in reg3. When these bits are false (0), the reg2 data is stored in reg3.

[Description]

- The assembler generates one cmovf.s machine instruction.

[Caution]

- If r0 is specified as reg3 in the cmovf.s instruction, the assembler outputs the following message and stops assembling.

```
E0550262 : Illegal operand (cannot use r0 as destination in RH850 mode).
```

trfsr

Flag transfer (Transfers specified CC bit to Zero flag in PSW (Single))

[Syntax]

- trfsr cc#3
- trfsr

[Function]

This instruction transfers the condition bits (the CC(7:0) bits: bits 31 to 24) in the FPSR register specified by fcbit to the Z flag in the PSW. If fcbit is omitted, this instruction transfers the CC0 bit (bit 24).

[Description]

- The assembler generates one trfsr machine instruction.

4.8.11 Other instructions

Other instructions are shown below.

- Virtualization support feature instructions
- Hardware multithreading feature instructions
- Cache instructions
- MMU control instructions
- SIMD instructions

Next table lists the floating-point operation instructions.

See the RH850 product user's manual and architecture edition for details.

CHAPTER 5 SECTION ALLOCATION

In an embedded application such as allocating program code from certain address or allocating by division, it is necessary to pay attention in the memory allocation.

To implement the memory allocation as expected, program code or data allocation information should be specified in optimizing linker.

5.1 Sections

A section is the basic unit making up programs (area to which programs or data are allocated). For example, program code is allocated to a text-attribute section and variables that have initial values are allocated to a data-attribute section. In other words, different types of information are allocated to different sections.

Section names can be specified within application. In C language, they can be specified using a #pragma section directive and in assembly language they can be specified using section definition directives.

Even if the #pragma directive is not used to specify a section, however, allocation by the compiler to a particular section may already be set as the default setting in the program code or data (variables).

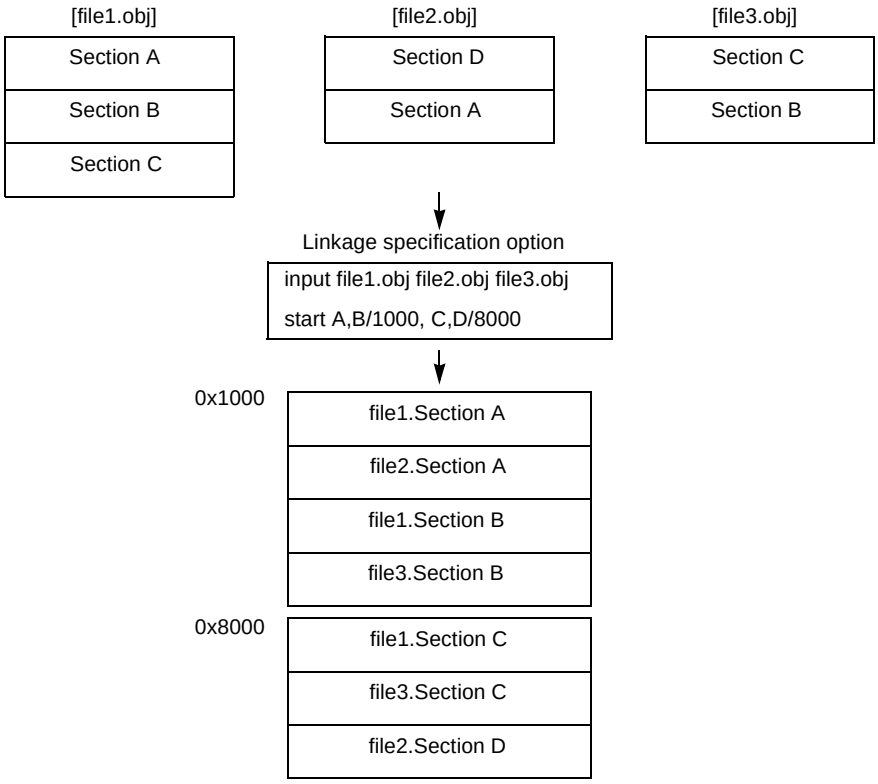
5.1.1 Section concatenation

The optimizing linker (hereafter abbreviated "rlink") concatenates identical sections in the input relocatable files, and allocates them to the address specified by the -start option.

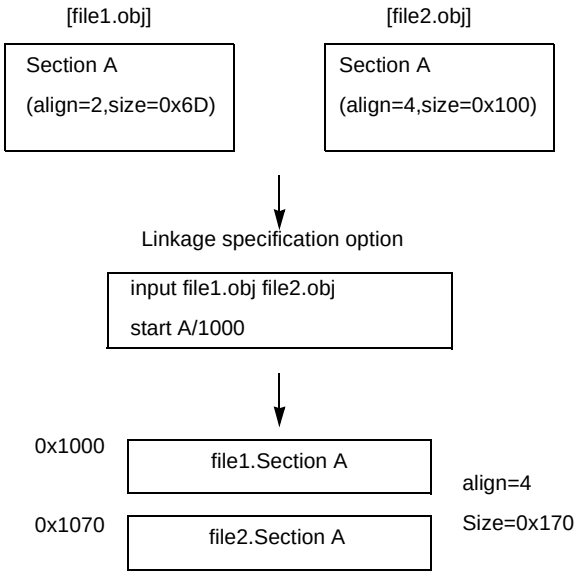
Remark See "CubeSuite+ Integrated Development Environment User's Manual: RH850 Build" for details of -start option.

(1) Section allocation via the -start option

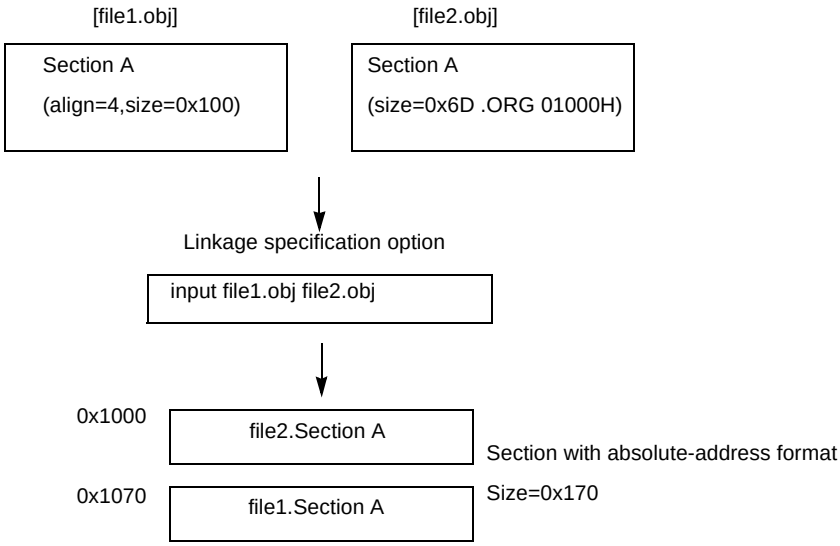
(a) Sections in different files with the same name are concatenated and allocated in the order of file input.



(b) Sections with the same name but different alignments are concatenated after alignment adjustment. The alignment is adjusted to that of the section with the largest alignment.

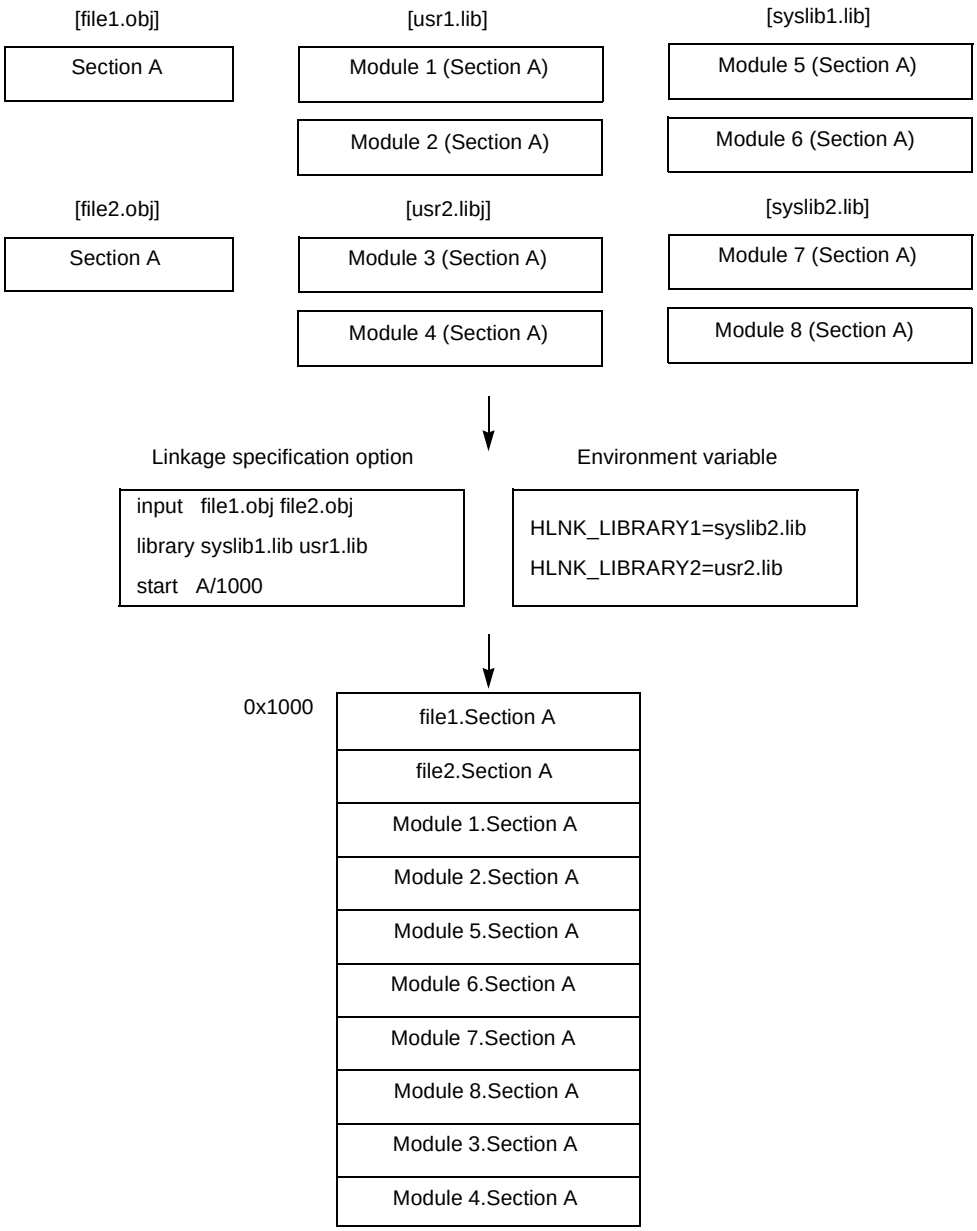


(c) If sections with the same name include both absolute-address format and relative-address format, then the sections with relative-address format are concatenated after the sections with absolute-address format.



(d) The rules for ordering of concatenation for sections with the same name are indicated below, highest priority to lowest.

- Order in which input files are specified via the input option or on the command line
- Order in which user libraries are specified via the library option and order of modules input in the library
- Order in which system libraries are specified via the library option and order of modules input in the library
- Order in which environment variable (HLNK_LIBRARY1 to 3) libraries are specified and order of modules input in the library



5.2 Special Symbol

The optimizing linker generates reserved symbols set to the values of the start addresses of each output section, and the first address beyond the end of each output section. If the user defines a symbol with the same name as one of these reserved symbols, then the optimizing linker will use the defined symbol, and will not generate its own.

The name of the reserved symbol with the value of the start address of a section is the name of that output section, preceded by the string "__s".

The name of the reserved symbol with the value of the first address after the end of a section is the name of that output section, preceded by the string "__e".

Below are shown the reserved sections and the special symbols corresponding to those sections.

Table 5-1. Special Symbol for Reserved Section

Reserved Section	Special Symbol for Reserved Section
.text	__s.text, __e.text

Reserved Section	Special Symbol for Reserved Section
.bss	__s.bss, __e.bss
.zbss	__s.zbss, __e.zbss
.zbss23	__s.zbss23, __e.zbss23
.ebss	__s.ebss, __e.ebss
.ebss23	__s.ebss23, __e.ebss23
.tbss4	__s.tbss4, __e.tbss4
.tbss5	__s.tbss5, __e.tbss5
.tbss7	__s.tbss7, __e.tbss7
.tbss8	__s.tbss8, __e.tbss8
.sbss	__s.sbss, __e.sbss
.sbss23	__s.sbss23, __e.sbss23
.data	__s.data, __e.data
.zdata	__s.zdata, __e.zdata
.zdata23	__s.zdata23, __e.zdata23
.edata	__s.edata, __e.edata
.edata23	__s.edata23, __e.edata23
.tdata	__s.tdata, __e.tdata
.tdata4	__s.tdata4, __e.tdata4
.tdata5	__s.tdata5, __e.tdata5
.tdata7	__s.tdata7, __e.tdata7
.tdata8	__s.tdata8, __e.tdata8
.sdata	__s.sdata, __e.sdata
.sdata23	__s.sdata23, __e.sdata23
.const	__s.const, __e.const
.zconst	__s.zconst, __e.zconst
.zconst23	__s.zconst23, __e.zconst23

Caution Only the symbols in the table for which there is a section in the post-linking executable file are generated.

CHAPTER 6 FUNCTIONAL SPECIFICATIONS

This chapter describes the library functions provided in the CC-RH.

6.1 Supplied Libraries

The CC-RH provides the following libraries.

Table 6-1. Supplied Libraries

Supplied Libraries	Library Name	Outline
Standard library	libc.lib	Program diagnosis function Function with variable arguments Character string functions Memory management functions Character conversion functions Character classification functions Standard I/O functions Standard utility functions Initialization peripheral devices function RAM section initialization function Operation runtime functions
	libsetjmp.lib	Non-local jump functions
Mathematical library (doble-precision)	libm.lib	Mathematical functions
Mathematical library (sngle-precision)	libmf.lib	

When the standard library or mathematical library is used in an application, include the related header files to use the library function.

Refer these libraries using the optimizing linker option (-l).

However, it is not necessary to refer the libraries if only "program diagnosis function", "function with a variable arguments", "character conversion functions" and "character classification functions" are used.

When CubeSuite+ is used, these libraries are referred by default.

The operation runtime function is a routine that is automatically called by the CC-RH when a floating-point operation or integer operation is performed.

Unlike the other library functions, the "operation runtime function" is not described in the C source or assembler source.

6.2 Header Files

The list of header files required for using the libraries of the CC-RH are listed below.

The macro definitions and function declarations are described in each file.

Table 6-2. Header Files

File Name	Outline
assert.h	Header file for program diagnostics
ctype.h	Header file for character conversion and classification
errno.h	Header file for reporting error condition

File Name	Outline
float.h	Header file for floating-point representation and floating-point operation
limits.h	Header file for quantitative limiting of integers
math.h	Header file for mathematical calculation
mathf.h	Header file for mathematical calculation (declares single-precision math functions and defines single-precision macros outside of the ANSI standard)
setjmp.h	Header file for non-local jump
stdarg.h	Header file for supporting functions having variable arguments
stddef.h	Header file for common definitions
stdio.h	Header file for standard I/O
stdlib.h	Header file for standard utilities
string.h	Header file for memory manipulation and character string manipulation
_h_c_lib.h	Header file for the initial setting routine

6.3 Re-entrant

"Re-entrant" means that the function can "re-enter". A re-entrant function can be correctly executed even if an attempt is made in another process to execute that function while the function is being executed. For example, in an application using a real-time OS, this function is correctly executed even if dispatching to another task is triggered by an interrupt while a certain task is executing this function, and even if the function is executed in that task. A function that must use RAM as a temporary area may not necessarily be re-entrant.

6.4 Library Function

This section explains Library Function.

6.4.1 Program diagnostic functions

Program diagnostic functions are as follows

Table 6-3. Program Diagnostic Function

Function/Macro Name	Outline
assert	Adds diagnostic features to the program

assert

Adds diagnostic features to the program.

[Classification]

Standard library

[Syntax]

#include <asssert.h>
assert(int *expression*);

[Description]

If expression is true, ends processing without returning a value. If expression is false, it outputs diagnostic information to the standard error file in the format defined by the compiler, and then calls the abort function[Note].

The diagnostic information includes the program text of the parameters, the name of the source file, and the line number of the source.

If you wish to disable the assert macro, include a #define NDEBUG statement before assert.h is loaded.

Note If you use the assert macro, you must create an abort function in accordance with the user system.

[Example]

```
#include    <assert.h>
int func(void);
int main() {
    int ret;
    ret = func();
    assert(ret == 0);       <- abort() is called if ret is not 0
    return 0;
}
```

6.4.2 Functions with variable arguments

Functions with a variable arguments are as follows

Table 6-4. Functions with Variable Arguments

Function/Macro Name	Outline
va_start	Initialization of variable for scanning argument list
va_end	End of scanning argument list
va_arg	Moving variable for scanning argument list

va_start

Initialization of variable for scanning argument list

[Classification]

Standard library

[Syntax]

#include <stdarg.h>
void va_start(va_list *ap*, *last-named-argument*);

[Description]

This function initializes variable *ap* so that it indicates the beginning (argument next to last-named-argument) of the list of the variable arguments.

To define function *func* having a variable arguments in a portable form, the following format is used.

```
#include    <stdarg.h>
void func(arg-declarations, ...) {
        va_list ap;
        type    argN;
        va_start(ap, last-named-argument);
        argN = va_arg(ap, type);
        va_end(ap);
}
```

Remark *arg-declarations* is an argument list with the *last-named-argument* declared at the end. ", ..." that follows indicates a list of the variable arguments. va_listis the type of the variable (*ap* in the above example) used to scan the argument list.

[Example]

```
#include    <stdarg.h>
void abc(int first, int second, ...) {
        va_list ap;
        int     i;
        char    c, *fmt;
        va_start(ap, second);
        i = va_arg(ap, int);
        c = va_arg(ap, int);        /*char type is converted into int type.*/
        fmt = va_arg(ap, char *);
        va_end(ap);
}
```

va_end

End of scanning argument list

[Classification]

Standard library

[Syntax]

```
#include <stdarg.h>
void    va_end(va_list ap);
```

[Description]

This function indicates the end of scanning the list. By enclosing va_arg between va_start and va_end, scanning the list can be repeated.

va_arg

Moving variable for scanning argument list

[Classification]

Standard library

[Syntax]

```
#include <stdarg.h>
type    va_arg(va_list ap, type);
```

[Description]

This function returns the argument indicated by variable *ap*, and advances variable *ap* to indicate the next argument. For the *type* of va_arg, specify the type converted when the argument is passed to the function. With the C compiler specify the int type for an argument of char and short types, and specify the unsigned int type for an argument of unsigned char and unsigned short types. Although a different type can be specified for each argument, stipulate "which type of argument is passed" according to the conventions between the called function and calling function.

Also stipulate "how many functions are actually passed" according to the conventions between the called function and calling function.

6.4.3 Character string functions

Character string functions are as follows.

Table 6-5. Character String Functions

Function/Macro Name	Outline
strpbrk	Character string search (start position)
strrchr	Character string search (end position)
strchr	Character string search (start position of specified character)
strstr	Character string search (start position of specified character string)
strspn	Character string search (maximum length including specified character)
strcspn	Character string search (maximum length not including specified character)
strcmp	Character string comparison
strncmp	Character string comparison (with number of characters specified)
strcpy	Character string copy
strncpy	Character string copy (with number of characters specified)
strcat	Character string concatenation
strncat	Character string concatenation (with number of characters specified)
strtok	Token division
strlen	Length of character string
strerror	Character string conversion of error number

strpbrk

Character string search (start position)

[Classification]

Standard library

[Syntax]

#include <string.h>
char *strpbrk(const char **s1*, const char **s2*);

[Return value]

Returns the pointer indicating this character. If any of the characters from *s2* does not appear in *s1*, the null pointer is returned.

[Description]

This function obtains the position in the character string indicated by *s1* at which any of the characters in the character string indicated by *s2* (except the null character (\0)) appears first.

strrchr

Character string search (end position)

[Classification]

Standard library

[Syntax]

```
#include <string.h>
char    *strrchr(const char *s, int c);
```

[Return value]

Returns a pointer indicating *c* that has been found. If *c* does not appear in this character string, the null pointer is returned.

[Description]

This function obtains the position at which *c* converted into char type appears last in the character string indicated by *s*. The null character (\0) indicating termination is regarded as part of this character string.

strchr

Character string search (start position of specified character)

[Classification]

Standard library

[Syntax]

```
#include <string.h>
char    *strchr(const char *s, int c);
```

[Return value]

Returns a pointer indicating the character that has been found. If *c* does not appear in this character string, the null pointer is returned.

[Description]

This function obtains the position at which a character the same as *c* converted into char type appears in the character string indicated by *s*. The null character (\0) indicating termination is regarded as part of this character string.

strstr

Character string search (start position of specified character)

[Classification]

Standard library

[Syntax]

```
#include <string.h>
char    *strstr(const char *s1, const char *s2);
```

[Return value]

Returns the pointer indicating the character string that has been found. If character string *s2* is not found, the null pointer is returned. If *s2* indicates a character string with a length of 0, *s1* is returned.

[Description]

This function obtains the position of the portion (except the null character (\0)) that first coincides with the character string indicated by *s2*, in the character string indicated by *s1*.

strspn

Character string search (maximum length including specified character)

[Classification]

Standard library

[Syntax]

#include <string.h>
size_t strspn(const char *s1, const char *s2);

[Return value]

Returns the length of the portion that has been found.

[Description]

This function obtains the maximum and first length of the portion consisting of only the characters (except the null character (\0)) in the character string indicated by *s2*, in the character string indicated by *s1*.

strcspn

Character string search (maximum length not including specified character)

[Classification]

Standard library

[Syntax]

#include <string.h>

size_t strcspn(const char *s1, const char *s2);

[Return value]

Returns the length of the portion that has been found.

[Description]

This function obtains the length of the maximum and first portion consisting of characters missing from the character string indicated by *s2* (except the null character (\0) at the end) in the character string indicated by *s1*.

strcmp

Character string comparison

[Classification]

Standard library

[Syntax]

#include <string.h>
int strcmp(const char *s1, const char *s2);

[Return value]

Returns an integer greater than, equal to, or less than 0, depending on whether the character string indicated by *s1* is greater than, equal to, or less than the character string indicated by *s2*.

[Description]

This function compares the character string indicated by *s1* with the character string indicated by *s2*.

strncmp

Character string comparison (with number of characters specified)

[Classification]

Standard library

[Syntax]

#include <string.h>
int strncmp(const char *s1, const char *s2, size_t *length*);

[Return value]

Returns an integer greater than, equal to, or less than 0, depending on whether the character string indicated by *s1* is greater than, equal to, or less than the character string indicated by *s2*.

[Description]

This function compares up to *length* characters of the array indicated by *s1* with characters of the array indicated by *s2*.

strcpy

Character string copy

[Classification]

Standard library

[Syntax]

#include <string.h>
char *strcpy(char **dst*, const char **src*);

[Return value]

Returns the value of *dst*.

[Description]

This function copies the character string indicated by *src* to the array indicated by *dst*.

[Example]

```
#include    <string.h>
void func(char *str, const char *src) {
        strcpy(str, src);   /*Copies character string indicated by src to array indicated by
                              str.*/
          :
}
```

strncpy

Character string copy (with number of characters specified)

[Classification]

Standard library

[Syntax]

```
#include <string.h>
char    *strncpy(char *dst, const char *src, size_t length);
```

[Return value]

Returns the value of *dst*.

[Description]

This function copies up to *length* characters (including the null character (\0)) from the array indicated by *src* to the array indicated by *dst*. If the array indicate by *src* is shorter than *length* characters, null characters (\0) are appended to the duplication in the array indicated by *dst*, until all *length* characters are written.

strcat

Character string concatenation

[Classification]

Standard library

[Syntax]

```
#include <string.h>
char    *strcat(char *dst, const char *src);
```

[Return value]

Returns the value of *dst*.

[Description]

This function concatenates the duplication of the character string indicated by *src* to the end of the character string indicated by *dst*, including the null character (\0). The first character of *src* overwrites the null character (\0) at the end of *dst*.

strncat

Character string concatenation (with number of characters specified)

[Classification]

Standard library

[Syntax]

```
#include <string.h>
char    *strncat(char *dst, const char *src, size_t length);
```

[Return value]

Returns the value of *dst*.

[Description]

This function concatenates up to *length* characters (including the null character (\0) of *src*) to the end of the character string indicated by *dst*, starting from the beginning of the character string indicated by *src*. The null character (\0) at the end of *dst* is written over the first character of *src*. The null character indicating termination (\0) is always added to this result.

[Caution]

Because the null character (\0) is always appended when strncat is used, if copying is limited by the number of *length* arguments, the number of characters appended to *dst* is *length* + 1.

strtok

Token division

[Classification]

Standard library

[Syntax]

```
#include <string.h>
char    *strtok(char *s, const char *delimiters);
```

[Return value]

Returns a pointer to a token. If a token does not exist, the null pointer is returned.

[Description]

This function divides the character string indicated by *s* into strings of tokens by delimiting the character string with a character in the character string indicated by *delimiters*. If this function is called first, *s* is used as the first argument. Then, calling with the null pointer as the first argument continues. The delimiting character string indicated by *delimiters* can differ on each call. On the first call, the character string indicated by s is searched for the first character not included in the delimiting character string indicated by *delimiters*. If such a character is not found, a token does not exist in the character string indicated by *s*, and strtok returns the null pointer. If a character is found, that character is the beginning of the first token. After that, strtok searches from the position of that character for a character included in the delimiting character string at that time.

If such a character is not found, the token is expanded to the end of the character string indicated by *s*, and the subsequent search returns the null pointer. If a character is found, the subsequent character is overwritten by the null character (\0) indicating the termination of the token. strtok saves the pointer indicating the subsequent character. If the null pointer is used as the value of the first argument, a code that is not re-entrant is returned. This can be avoided by preserving the address of the last delimiting character in the application program, and passing *s* as an argument that is not vacant, by using this address.

strlen

Length of character string

[Classification]

Standard library

[Syntax]

```
#include <string.h>
size_t  strlen(const char *s);
```

[Return value]

Returns the number of characters existing before the null character (\0) indicating termination.

[Description]

This function obtains the length of the character string indicated by *s*.

strerror

Character string conversion of error number

[Classification]

Standard library

[Syntax]

#include <string.h>
char *strerror(int *errnum*);

[Return value]

Returns a pointer to the converted character string.

[Description]

This function converts error number *errnum* into a character string according to the correspondence relationship of the processing system definition. The value of *errnum* is usually the duplication of global variable errno. Do not change the specified array of the application program.

6.4.4 Memory management functions

Memory management functions are as follows.

Table 6-6. Memory Management Functions

Function/Macro Name	Outline
memchr	Memory search
memcmp	Memory comparison
memcpy	Memory copy
memmove	Memory move
memset	Memory set

memchr

Memory search

[Classification]

Standard library

[Syntax]

```
#include <string.h>
void    *memchr(const void *s, int c, size_t length);
```

[Return value]

If *c* is found, a pointer indicating this character is returned. If *c* is not found, the null pointer is returned.

[Description]

This function obtains the position at which character *c* (converted into char type) appears first in the first *length* number of characters in an area indicated by *s*.

memcmp

Memory comparison

[Classification]

Standard library

[Syntax]

#include <string.h>
int memcmp(const void *s1, const void *s2, size_t n);

[Return value]

An integer greater than, equal to, or less than *0* is returned, depending on whether the object indicated by *s1* is greater than, equal to, or less than the object indicated by *s2*.

[Description]

This function compares the first n characters of an object indicated by *s1* with the object indicated by *s2*.

[Example]

```
#include    <string.h>
int func(const void *s1, const void *s2) {
        int i;
        i = memcmp(s1, s2, 5);  /*Compares the first five characters of the character
                                  string indicated by s1 with the first five characters of
                                  the character string indicated by s2.*/
        return(i);
}
```

memcpy

Memory copy

[Classification]

Standard library

[Syntax]

```
#include <string.h>
void    *memcpy(void *out, const void *in, size_t n);
```

[Return value]

Returns the value of *out*. The operation is undefined if the copy source and copy destination areas overlap.

[Description]

This function copies *n* bytes from an object indicated by *in* to an object indicated by *out*.

memmove

Memory move

[Classification]

Standard library

[Syntax]

```
#include <string.h>
void    *memmove(void *dst, void *src, size_t length);
```

[Return value]

Returns the value of *dst* at the copy destination.

[Description]

This function moves the *length* number of characters from a memory area indicated by *src* to a memory area indicated by *dst*. Even if the copy source and copy destination areas overlap, the characters are correctly copied to the memory area indicated by *dst*.

memset

Memory set

[Classification]

Standard library

[Syntax]

```
#include <string.h>
void    *memset(const void *s, int c, size_t length);
```

[Return value]

Returns the value of *s*.

[Description]

This function copies the value of *c* (converted into unsigned char type) to the first *length* character of an object indicated by *s*.

6.4.5 Character conversion functions

Character conversion functions are as follows.

Table 6-7. Character Conversion Functions

Function/Macro Name	Outline
toupper	Conversion from lower-case to upper-case (not converted if argument is not in lower-case)
tolower	Conversion from upper-case to lower-case (not converted if argument is not in upper-case)

toupper

Conversion from lower-case to upper-case (not converted if argument is not in lower-case)

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int toupper(int *c*);

[Return value]

If islower is true with respect to *c*, returns a character that makes isupper true in response; otherwise, returns *c*.

[Description]

This function is a macro that converts lowercase characters into the corresponding uppercase characters and leaves the other characters unchanged.

This macro is defined only when *c* is an integer in the range of EOF to 255. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef toupper".

[Example]

```
#include    <ctype.h>
int c = 'a';
int func() {
        int i;
        i = toupper(c);         /*Converts lowercase character 'a' of c into uppercase
                                  character 'A'.*/
        return(i);
}
```

tolower

Conversion from upper-case to lower-case (not converted if argument is not in upper-case)

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int tolower(int *c*);

[Return value]

If isupper is true with respect to c, returns a character that makes islower true in response; otherwise, returns *c*.

[Description]

This function is a macro that converts uppercase characters into the corresponding lowercase characters and leaves the other characters unchanged.

This macro is defined only when *c* is an integer in the range of EOF to 255. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef tolower".

6.4.6 Character classification functions

Character classification functions are as follows.

Table 6-8. Character Classification Functions

Function/Macro Name	Outline
isalnum	Identification of ASCII letter or numeral
isalpha	Identification of ASCII letter
isascii	Identification of ASCII code
isupper	Identification of upper-case character
islower	Identification of lower-case character
isdigit	Identification of decimal number
isxdigit	Identification of hexadecimal number
iscntrl	Identification of control character
ispunct	Identification of delimiter character
isspace	Identification of space/tab/carriage return/line feed/vertical tab/page feed
isprint	Identification of display character
isgraph	Identification of display character other than space

isalnum

Identification of ASCII letter or numeral

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int isalnum(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is an ASCII alphabetic character or numeral. This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef isalnum".

isalpha

Identification of ASCII letter

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int isalpha(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is an ASCII alphabetic character. This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef isalpha".

isascii

Identification of ASCII code

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int isascii(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is an ASCII code (0x00 to 0x7F). This macro is defined for all integer values. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef isascii".

isupper

Identification of upper-case character

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int isupper(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is an uppercase character (A to Z). This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef isupper".

islower

Identification of lower-case character

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int islower(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is a lowercase character (a to z). This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef islower".

isdigit

Identification of decimal number

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int isdigit(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is a decimal number. This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef isdigit".

isxdigit

Identification of hexadecimal number

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int isxdigit(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is a hexadecimal number (0 to 9, a to f, or A to F). This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef isxdigit".

iscntrl

Identification of control character

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int iscntrl(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is a control character (0x00 to 0x1F or 0x7F). This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef iscntrl".

ispunct

Identification of delimiter character

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int ispunct(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is a printable delimiter (isgraph(c) && !isalnum(c)). This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef ispunct".

isspace

Identification of space/tab/carriage return/line feed/vertical tab/page feed

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int isspace(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is a space, tap, line feed, carriage return, vertical tab, or form feed (0x09 to 0x0D, or 0x20). This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef isspace".

isprint

Identification of display character

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int isprint(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is a display character (0x20 to 0x7E). This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef isprint".

[Example]

```
#include    <ctype.h>
void func(void) {
        int     i, j = 0;
        char    s[50];
                for (i =50; i <= 99; i++) {
                        if (isprint(i)) {   /*Store the printable characters in the code
                                              range 50 to 99, in the array s.*/
                        s[j] = i;
                        j++;
                        }
                }
        :
}
```

isgraph

Identification of display character other than space

[Classification]

Standard library

[Syntax]

#include <ctype.h>
int isgraph(int *c*);

[Return value]

These macros return a value other than 0 if the value of argument *c* matches the respective description (i.e., if the result is true). If the result is false, 0 is returned.

[Description]

This function is a macro that checks whether a given character is a display character[Note] (0x20 to 0x7E) other than space (0x20). This macro is defined only when *c* is made true by isascii or when *c* is EOF. A compiled subroutine can be used instead of the macro definition, which is invalidated by using "#undef isgraph".

Note printing character

6.4.7 Standard I/O functions

Standard I/O functions are as follows.

Table 6-9. Standard I/O Functions

Function/Macro Name	Outline
fread	Read from stream
getc	Read character from stream (same as fgetc)
fgetc	Read character from stream (same as getc)
fgets	Read one line from stream
fwrite	Write to stream
putc	Write character to stream (same as fputc)
fputc	Write character to stream (same as putc)
fputs	Output character string to stream
getchar	Read one character from standard input
gets	Read character string from standard input
putchar	Write character to standard output stream
puts	Output character string to standard output stream
sprintf	Output with format
fprintf	Output text in specified format to stream
vsprintf	Write text in specified format to character string
printf	Output text in specified format to standard output stream
vfprintf	Write text in specified format to stream
vprintf	Write text in specified format to standard output stream
sscanf	Input with format
fscanf	Read and interpret data from stream
scanf	Read and interpret text from standard input stream
ungetc	Push character back to input stream
rewind	Reset file position indicator
perror	Error processing

fread

Read from stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
size_t fread(void *_ptr_, size_t _size_, size_t _nmemb_, FILE *_stream_);

[Return value]

The number of elements that were input (_nmemb_) is returned.
Error return does not occur.

[Description]

This function inputs _nmemb_ elements of _size_ from the input stream pointed to by _stream_ and stores them in _ptr_. Only the standard input/output stdin can be specified for _stream_.

[Example]

```
#include    <stdio.h>
void func(void) {
        struct {
                int     c;
                double  d;
        } buf[10];
        fread(buf, sizeof(buf[0]), sizeof(buf) / sizeof(buf [0]), stdin);
}
```

getc

Read character from stream (same as fgetc)

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

```
#include <stdio.h>
int getc(FILE *stream);
```

[Return value]

The input character is returned.
Error return does not occur.

[Description]

This function inputs one character from the input stream pointed to by *stream*. Only the standard input/output stdin can be specified for *stream*.

fgetc

Read character from stream (same as getc)

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int fgetc(FILE *_stream_);

[Return value]

The input character is returned.
Error return does not occur.

[Description]

This function inputs one character from the input stream pointed to by *stream*. Only the standard input/output stdin can be specified for *stream*.

[Example]

```
#include    <stdio.h>

int func(void) {
        int c;
        c = fgetc(stdin);
        return(c);
}
```

fgets

Read one line from stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

```
#include <stdio.h>
char    *fgets(char *s, int n, FILE *stream);
```

[Return value]

s is returned.
Error return does not occur.

[Description]

This function inputs at most *n-1* characters from the input stream pointed to by *stream* and stores them in *s*. Character input is also ended by the detection of a new-line character. In this case, the new-line character is also stored in *s*. The end-of-string null character is stored at the end in *s*. Only the standard input/output stdin can be specified for *stream*.

fwrite

Write to stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
size_t fwrite(const void *_ptr_, size_t _size_, size_t _nmemb_, FILE *_stream_);

[Return value]

The number of elements that were output (_nmemb_) is returned.
Error return does not occur.

[Description]

This function outputs _nmemb_ elements of _size_ from the array pointed to by _ptr_ to the output stream pointed to by _stream_. Only the standard input/output stdout or stderr can be specified for _stream_.

putc

Write character to stream (same as fputc)

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int putc(int *c*, FILE **stream*);

[Return value]

The character *c* is returned.
Error return does not occur.

[Description]

This function outputs the character *c* to the output stream pointed to by *stream.* Only the standard input/output stdout or stderr can be specified for *stream*.

fputc

Write character to stream (same as putc)

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int fputc(int *c*, FILE **stream*);

[Return value]

The character *c* is returned.
Error return does not occur.

[Description]

This functionoutputs the character *c* to the output stream pointed to by *stream*. Only the standard input/output stdout or stderr can be specified for *stream*.

[Example]

```
#include    <stdio.h>
void func(void) {
        fputc('a', stdout);
}
```

fputs

Output character string to stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int fputs(const char *s, FILE *stream);

[Return value]

0 is returned.
Error return does not occur.

[Description]

This function outputs the string *s* to the output stream pointed to by *stream*. The end-of-string null character is not output. Only the standard input/output stdout or stderr can be specified for *stream*.

getchar

Read one character from standard input

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

```
#include <stdio.h>
int getchar(void);
```

[Return value]

The input character is returned.
Error return does not occur.

[Description]

This function inputs one character from the standard input/output stdin.

gets

Read character string from standard input

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

```
#include <stdio.h>
char    *gets(char *s);
```

[Return value]

s is returned.
Error return does not occur.

[Description]

This function inputs characters from the standard input/output stdin until a new-line character is detected and stores them in *s*. The new-line character that was input is discarded, and an end-of-string null character is stored at the end in *s*.

putchar

Write character to standard output stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int putchar(int *c*);

[Return value]

The character *c* is returned.
Error return does not occur.

[Description]

This function outputs the character *c* to the standard input/output stdout.

puts

Output character string to standard output stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

```
#include <stdio.h>
int puts(const char *s);
```

[Return value]

0 is returned.
Error return does not occur.

[Description]

This function outputs the string *s* to the standard input/output stdout. The end-of-string null character is not output, but a new-line character is output in its place.

sprintf

Output with format

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int sprintf(char *s, const char **format*[, *arg*, ...]);

[Return value]

The number of characters that were output (excluding the null character (\0)) is returned.
Error return does not occur.

[Description]

This function applies the format specified by the string pointed to by *format* to the respective *arg* arguments, and writes out the formatted data that was output as a result to the array pointed to by *s*.

If there are not sufficient arguments for the format, the operation is undefined. If the end of the formatted string is reached, control returns. If there are more arguments that those required by the format, the excess arguments are ignored. If the area of *s* overlaps one of the arguments, the operation is undefined.

The argument *format* specifies "the output to which the subsequent argument is to be converted". The null character (\0) is appended at the end of written characters (the null character (\0) is not counted in a return value).

The *format* consists of the following two types of directives:

Ordinary characters	Characters that are copied directly without conversion (other than "%").
Conversion specifications	Specifications that fetch zero or more arguments and assign a specification.

Each conversion specification begins with character "%" (to insert "%" in the output, specify "%%" in the format string). The following appear after the "%":

%[flag][field-width][precision][size][type-specification-character]

The meaning of each conversion specification is explained below.

(1) flag

Zero or more flags, which qualify the meaning of the conversion specification, are placed in any order.
The flag characters and their meanings are as follows:

-	The result of the conversion will be left-justified in the field, with the right side filled with blanks (if this flag is not specified, the result of the conversion is right-justified).
+	The result of a signed conversion will start with a + or - sign (if this flag is not specified, the result of the conversion starts with a sign only when a negative value has been converted).
Space	If the first character of a signed conversion is not a sign and a signed conversion is not generated a character, a space (" ") will be appended to the beginning of result of the conversion. If both the space flag and + flag appear, the space flag is ignored.

#	The result is to be converted to an alternate format. For o conversion, the precision is increased so that the first digit of the conversion result is 0. For x or X conversion, 0x or 0X is appended to the beginning of a non-zero conversion result. For e, f, g, E, or G conversion, a decimal point "." is added to the conversion result even if no digits follow the decimal point[Note]. For g or G conversion, trailing zeros will not be removed from the conversion result. The operation is undefined for conversions other than the above.
0	For d, e, f, g, i, o, u, x, E, G, or X conversion, zeros are added following the specification of the sign or base to fill the field width. If both the 0 flag and - flag are specified, the 0 flag is ignored. For d, i, o, u, x, or X conversion, when the precision is specified, the zero (0) flag is ignored. Note that 0 is interpreted as a flag and not as the beginning of the field width. The operation is undefined for conversion other than the above.

Note Normally, a decimal point appears only when a digit follows it.

(2) field width

This is an optional minimum field width. If the converted value is smaller than this field width, the left side is filled with spaces (if the left justification flag explained above is assigned, the right side will be filled with spaces). This field width takes the form of "*" or a decimal integer. If "*" is specified, an int type argument is used as the field width. A negative field width is not supported. If an attempt is made to specify a negative field width, it is interpreted as a minus (-) flag appended to the beginning of a positive field width.

(3) precision

For d, i, o, u, x, or X conversion, the value assigned for the precision is the minimum number of digits to appear. For e, f, or E conversion, it is the number of digits to appear after the decimal point. For g or G conversion, it is the maximum number of significant digits. The precision takes the form of "*" or "." followed by a decimal integer. If "*" is specified, an int type argument is used as the precision. If a negative precision is specified, it is treated as if the precision were omitted. If only "." is specified, the precision is assumed to be 0. If the precision appears together with a conversion specification other than the above, the operation is undefined.

(4) size

This is an arbitrary optional size character h, l, ll, or L, which changes the default method for interpreting the data type of the corresponding argument.

When h is specified, a following d, i, o, u, x, or X type specification is forcibly applied to a short or unsigned short argument.

When l is specified, a following d, i, o, u, x, or X type specification is forcibly applied to a long or unsigned long argument. l is also causes a following n type specification to be forcibly applied to a pointer to long argument. If another type specification character is used together with h or l, the operation is undefined.

When ll is specified, a following d, i, o, u, x, or X type specification is forcibly applied to a long long and unsigned long long argument. Furthermore, for ll, a following n type specification is forcibly applied to a long long pointer. If another type specification character is used together with ll, the operation is undefined.

When L is specified, a following e, E, f, g, or G type specification is forcibly applied to a long double argument. If another type specification character is used together with L, the operation is undefined.

(5) type specification character

These are characters that specify the type of conversion that is to be applied.

The characters that specify conversion types and their meanings are as follows.

%	Output the character "%". No argument is converted. The conversion specification is "%%".
c	Convert an int type argument to unsigned char type and output the characters of the conversion result.

d	Convert an int type argument to a signed decimal number.
e, E	Convert a double type argument to [-]d.dddde±dd format, which has one digit before the decimal point (not 0 if the argument is not 0) and the number of digits after the decimal point is equal to the precision. The E conversion specification generates a number in which the exponent part starts with "E" instead of "e".
f	Convert a double type argument to decimal notation of the form [-]dddd.dddd.
g, G	Convert a double type argument to e (E for a G conversion specification) or f format, with the number of digits in the mantissa specified for the precision. Trailing zeros of the conversion result are excluded from the fractional part. The decimal point appears only when it is followed by a digit.
i	Perform the same conversion as d.
n	Store the number of characters that were output in the same object. A pointer to int type is used as the argument.
p	Output a pointer in an implementation-defined format. The CC-RH handles a pointer as unsigned long (this is the same as the lu specification).
o, u, x, X	Convert an unsigned int type argument to octal notation (o), unsigned decimal notation (u), or unsigned hexadecimal notation (x or X) with dddd format. For x conversion, the letters abcdef are used. For X conversion, the letters ABCDEF are used.
s	The argument must be a pointer pointing to a character type array. Characters from this array are output up until the null character (\0) indicating termination (the null character (\0) itself is not included). If the precision is specified, no more than the specified number of characters will be output. If the precision is not specified or if the precision is greater than the size of this array, make sure that this array includes the null character (\0).

[Example]

```
#include    <stdio.h>
void func(int val) {
        char    s[20];
        sprintf(s, "%-10.51x\n", val);  /*Specifies left-justification, field width 10,
                                          precision 5, size long, and hexadecimal notation
                                          for the value of val, and outputs the result
                                          with an appended new-line character to the array
                                          pointed to by s.*/
}
```

fprintf

Output text in specified format to stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int fprintf(FILE **stream*, const char **format*[, *arg*, ...]);

[Return value]

The number of characters that were output is returned.

[Description]

This function applies the format specified by the string pointed to by *format* to the respective *arg* arguments, and outputs the formatted data that was output as a result to *stream*. Only the standard input/output stdout or stderr can be specified for *stream*. The method of specifying *format* is the same as described for the sprintf function. However, fprintf differs from sprintf in that no null character (\0) is output at the end.

[Caution]

Stdin (standard input) and stdout (standard error) are specified for the argument *stream*. 1 memory addresses such as an I/O address is allocated for the I/O destination of stream. To use these streams in combination with a debugger, the initial values of the stream structure defined in stdio.h must be set. Be sure to set the initial values prior to calling the function.

[Definition of stream structure in stdio.h]

```
typedef struct {
        int         mode;   /*with error descriptions*/
        unsigend    handle;
        int         unget_c;
} FILE;
typedef int     fpos_t;

extern  FILE*   _REL_stdin();
extern  FILE*   _REL_stdout();
extern  FILE*   _REL_stderr();
#define stdin   (_REL_stdin())
#define stdout  (_REL_stdout())
#define stderr  (_REL_stderr())
```

The first structure member, mode, indicates the I/O status and is internally defined as ACCSD_OUT/ADDSD_IN. The third member, unget_c, indicates the pushed-back character (stdin only) setting and is internally defined as -1.

When the definition is -1, it indicates that there is no pushed-back character. The second member, handle, indicates the I/O address. Set the value according to the debugger to be used.

[I/O address setting]

```
stdout->handle = 0xfffff000;
stderr->handle = 0x00fff000;
stdin->handle  = 0xfffff002;
```

[Example]

```
#include    <stdio.h>
void func(int val) {
        fprintf(stdout, "%-10.5x\n", val);
}
/*Example using vfprintf in a general error reporting routine.*/
void error(char *function_name, char *format, ...) {
        va_list arg;
        va_start(arg, format);
        fprintf(stderr, "ERROR in %s:", function_name); /*output function name for which
                                                          error occurred*/
        vfprintf(stderr, format, arg);                  /*output remaining messages*/
        va_end(arg);
}
```

vsprintf

Write text in specified format to character string

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int vsprintf(char *s, const char *format, va_list *arg*);

[Return value]

The number of characters that were output (excluding the null character (\0)) is returned.
Error return does not occur.

[Description]

This function applies the format specified by the string pointed to by *format* to the argument string pointed to by *arg*, and outputs the formatted data that was output as a result to the array pointed to be *s*. The vsprintf function is equivalent to sprintf with the list of a variable number of real arguments replaced by *arg*. *arg* must be initialized by the va_start macro before the vsprintf function is called.

printf

Output text in specified format to standard output stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int printf(const char **format*[, *arg*, ...]);

[Return value]

The number of characters that were output is returned.

[Description]

This function applies the format specified by the string pointed to by *format* to the respective *arg* arguments, and outputs the formatted data that was output as a result to the standard input/output stdout. The method of specifying *format* is the same as described for the sprintf function. However, printf differs from sprintf in that no null character (\0) is output at the end.

[Caution]

Assigns one memory address (e.g. an I/O address) to stdout. To use stdout in conjunction with a debugger, you must initialize the stream structure defined in the stdio.h file. Initialize the structure before calling the function.

[Definition of stream structure in stdio.h]

```
typedef struct {
        int         mode;   /*with error descriptions*/
        unsigend    handle;
        int         unget_c;
} FILE;
typedef int     fpos_t;

extern  FILE*   _REL_stdin();
extern  FILE*   _REL_stdout();
extern  FILE*   _REL_stderr();
#define stdin   (_REL_stdin())
#define stdout  (_REL_stdout())
#define stderr  (_REL_stderr())
```

The first structure member, mode, indicates the I/O status and is internally defined as ACCSD_OUT/ADDSD_IN. The third member, unget_c, indicates the pushed-back character (stdin only) setting and is internally defined as -1.

When the definition is -1, it indicates that there is no pushed-back character. The second member, handle, indicates the I/O address. Set the value according to the debugger to be used.

[I/O address setting]

```
stdout->handle = 0xfffff000;
stderr->handle = 0x00fff000;
stdin->handle  = 0xfffff002;
```

vfprintf

Write text in specified format to stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int vfprintf(FILE **stream*, const char **format*, va_list *arg*);

[Return value]

The number of characters that were output is returned.

[Description]

This function applies the format specified by the string pointed to by *format* to argument string pointed to by *arg*, and outputs the formatted data that was output as a result to *stream*. Only the standard input/output stdout or stderr can be specified for *stream*. The method of specifying *format* is the same as described for the sprintf function. The vfprintf function is equivalent to fprintf with the list of a variable number of real arguments replaced by *arg*. *arg* must be initialized by the va_start macro before the vfprintf function is called.

[Caution]

Stdout (standard output) and stderr (standard error) are specified for the argument *stream*. 1 memory addresses such as an I/O address is allocated for the I/O destination of stream. To use these streams in combination with a debugger, the initial values of the stream structure defined in stdio.h must be set. Be sure to set the initial values prior to calling the function.

[Definition of stream structure in stdio.h]

```
typedef struct {
        int         mode;   /*with error descriptions*/
        unsigend    handle;
        int         unget_c;
} FILE;
typedef int     fpos_t;

extern  FILE*   _REL_stdin();
extern  FILE*   _REL_stdout();
extern  FILE*   _REL_stderr();
#define stdin   (_REL_stdin())
#define stdout  (_REL_stdout())
#define stderr  (_REL_stderr())
```

The first structure member, mode, indicates the I/O status and is internally defined as ACCSD_OUT/ADDSD_IN. The third member, unget_c, indicates the pushed-back character (stdin only) setting and is internally defined as -1.

When the definition is -1, it indicates that there is no pushed-back character. The second member, handle, indicates the I/O address. Set the value according to the debugger to be used.

[I/O address setting]

```
stdout->handle = 0xfffff000;
stderr->handle = 0x00fff000;
stdin->handle  = 0xfffff002;
```

[Example]

```
#include    <stdio.h>
void func(int val) {
        fprintf(stdout, "%-10.5x\n", val);
}
/*example using vfprintf in a general error reporting routine*/
void error(char *function_name, char *format, ...) {
        va_list arg;
        va_start(arg, format);
        fprintf(stderr, "ERROR in %s:", function_name); /*output function name for which
                                                          error occurred*/
        vfprintf(stderr, format, arg);                  /*output remaining messages*/
        va_end(arg);
}
```

vprintf

Write text in specified format to standard output stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int vprintf(const char **format*, va_list *arg*);

[Return value]

The number of characters that were output is returned.

[Description]

This function applies the format specified by the string pointed to by *format* to the argument string pointed to by *arg*, and outputs the formatted data that was output as a result to the standard input/output stdout. The method of specifying *format* is the same as described for the sprintf function. The vprintf function is equivalent to printf with the list of a variable number of real arguments replaced by *arg*. *arg* must be initialized by the va_start macro before the vprintf function is called.

[Caution]

Stdout (standard output) and stderr (standard error) are specified for the argument *stream*. 1 memory addresses such as an I/O address is allocated for the I/O destination of stream. To use these streams in combination with a debugger, the initial values of the stream structure defined in stdio.h must be set. Be sure to set the initial values prior to calling the function.

[Definition of stream structure in stdio.h]

```
typedef struct {
        int         mode;   /*with error descriptions*/
        unsigend    handle;
        int         unget_c;
} FILE;
typedef int     fpos_t;

extern  FILE*   _REL_stdin();
extern  FILE*   _REL_stdout();
extern  FILE*   _REL_stderr();
#define stdin   (_REL_stdin())
#define stdout  (_REL_stdout())
#define stderr  (_REL_stderr())
```

The first structure member, mode, indicates the I/O status and is internally defined as ACCSD_OUT/ADDSD_IN. The third member, unget_c, indicates the pushed-back character (stdin only) setting and is internally defined as -1.

When the definition is -1, it indicates that there is no pushed-back character. The second member, handle, indicates the I/O address. Set the value according to the debugger to be used.

[I/O address setting]

```
stdout->handle = 0xfffff000;
stderr->handle = 0x00fff000;
stdin->handle  = 0xfffff002;
```

sscanf

nput with format

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int sscanf(const char *s, const char *format[, arg, ...]);

[Return value]

The number of input fields for which scanning, conversion, and storage were executed normally is returned. The return value does not include scanned fields that were not stored. If an attempt is made to read to the end of the file, the return value is EOF. If no field was stored, the return value is 0.

[Description]

This function reads the input to be converted according to the *format* specified by the character string pointed to by format from the array pointed to by *s* and treats the *arg* arguments that follow format as pointers that point to objects for storing the converted input.

An input string that can be recognized and "the conversion that is to be performed for assignment" are specified for *format*. If sufficient arguments do not exist for *format*, the operation is undefined. If *format* is used up even when arguments remain, the remaining arguments are ignored.

The *format* consists of the following three types of directives:

One or more Space characters	Space ( ), tab (\t), or new-line (\n). If a space character is found in the string when sscanf is executed, all consecutive space characters are read until the next non-space character appears (the space characters are not stored).
Ordinary characters	All ASCII characters other than "%". If an ordinary character is found in the string when sscanf is executed, that character is read but not stored. sscanf reads a string from the input field, converts it into a value of a specific type, and stores it at the position specified by the argument, according to the conversion specification. If an explicit match does not occur according to the conversion specification, no subsequent space character is read.
Conversion specification	Fetches 0 or more arguments and directs the conversion.

Each conversion specification starts with "%". The following appear after the "%":

%[assignment-suppression-character][field-width][size][type-specification-character]

Each conversion specification is explained below.

(1) Assignment suppression character

The assignment suppression character "*" suppresses the interpretation and assignment of the input field.

(2) field width

This is a non-zero decimal integer that defines the maximum field width.

It specifies the maximum number of characters that are read before the input field is converted. If the input field is smaller than this field width, sscanf reads all the characters in the field and then proceeds to the next field and its conversion specification.

If a space character or a character that cannot be converted is found before the number of characters equivalent to the field width is read, the characters up to the white space or the character that cannot be converted are read and stored. Then, sscanf proceeds to the next conversion specification.

(3) size

This is an arbitrary optional size character h, l, ll, or L, which changes the default method for interpreting the data type of the corresponding argument.

When h is specified, a following d, i, n, o, u, or x type specification is forcibly converted to short int type and stored as short type. Nothing is done for c, e, f, n, p, s, D, I, O, U, or X.

When l is specified, a following d, i, n, o, u, or x type specification is forcibly converted to long int type and stored as long type. An e, f, or g type specification is forcibly converted to double type and stored as double type. Nothing is done for c, n, p, s, D, I, O, U, and X.

When ll is specified, a following d, i, o, u, x, or X type specification is forcibly converted to long long type and stored as long long type. Nothing is done for other type specifications.

When L is specified, a following e, f, or g type specification is forcibly converted to long double type and stored as long double type. Nothing is done for other type specifications.

In cases other than the above, the operation is undefined.

(4) type specification character

These are characters that specify the type of conversion that is to be applied.

The characters that specify conversion types and their meanings are as follows.

%	Match the character "%". No conversion or assignment is performed. The conversion specification is "%%".
c	Scan one character. The corresponding argument should be "char **arg*".
d	Read a decimal integer into the corresponding argument. The corresponding argument should be "int **arg*".
e, f, g	Read a floating-point number into the corresponding argument. The corresponding argument should be "float **arg*".
i	Read a decimal, octal, or hexadecimal integer into the corresponding argument. The corresponding argument should be "int **arg*".
n	Store the number of characters that were read in the corresponding argument. The corresponding argument should be "int **arg*".
o	Read an octal integer into the corresponding argument. The corresponding argument must be "int **arg*".
p	Store the pointer that was scanned. This is an implementation definition. The ca processes %p and %U in exactly the same manner. The corresponding argument should be "void ***arg*".
s	Read a string into a given array. The corresponding argument should be "char *arg*[ ]".
u	Read an unsigned decimal integer into the corresponding argument. The corresponding argument should be "unsigned int **arg*".
x, X	Read a hexadecimal integer into the corresponding argument. The corresponding argument should be "int **arg*".

D	Read a decimal integer into the corresponding argument. The corresponding argument should be "long *arg".
E, F, G	Read a floating-point number into the corresponding argument. The corresponding argument should be "double *arg".
I	Read a decimal, octal, or hexadecimal integer into the corresponding argument. The corresponding argument should be "long *arg".
O	Read an octal integer into the corresponding argument. The corresponding argument should be "long *arg".
U	Read an unsigned decimal integer into the corresponding argument. The corresponding argument should be "unsigned long *arg".
[ ]	Read a non-empty string into the memory area starting with argument *arg*. This area must be large enough to accommodate the string and the null character (\0) that is automatically appended to indicate the end of the string. The corresponding argument should be "char *arg". The character pattern enclosed by [ ] can be used in place of the type specification character s. The character pattern is a character set that defines the search set of the characters constituting the input field of sscanf. If the first character within [ ] is "^", the search set is complemented, and all ASCII characters other than the characters within [ ] are included. In addition, a range specification feature that can be used as a shortcut is also available. For example, %[0-9] matches all decimal numbers. In this set, "-" cannot be specified as the first or last character. The character preceding "-" must be less in lexical sequence than the succeeding character. - %[abcd] Matches character strings that include only a, b, c, and d. - %[^abcd] Matches character strings that include any characters other than a, b, c, and d. - %[A-DW-Z] Matches character strings that include A, B, C, D, W, X, Y, and Z. - %[z-a] Matches z, -, and a (this is not considered a range specification).

Make sure that a floating-point number (type specification characters e, f, g, E, F, and G) corresponds to thefollowing general format.

[+ | -] ddddd [.] ddd [E | e [+ | -] ddd]

However, the portions enclosed by [ ] in the above format are arbitrarily selected, and ddd indicates a decimal digit.

[Caution]

- sscanf may stop scanning a specific field before the normal end-of-field character is reached or may stop completely.
- sscanf stops scanning and storing a field and moves to the next field under the following conditions.
  - The substitution suppression character (*) appears after "%" in the format specification, and the input field at that point has been scanned but not stored.
  - A field width (positive decimal integer) specification character was read.
  - The character to be read next cannot be converted according to the conversion specification (for example, if Z is read when the specification is a decimal number).
  - The next character in the input field does not appear in the search set (or appears in the complement search set).

  If sscanf stops scanning the input field at that point because of any of the above reasons, it is assumed that the next character has not yet been read, and this character is used as the first character of the next field or the first character for the read operation to be executed after the input.
- sscanf ends under the following conditions:
  - The next character in the input field does not match the corresponding ordinary character in the string to be converted.
  - The next character in the input field is EOF.
  - The string to be converted ends.
- If a list of characters that is not part of the conversion specification is included in the string to be converted, make sure that the same list of characters does not appear in the input. sscanf scans matching characters but does not store them. If there was a mismatch, the first character that does not match remains in the input as if it were not read.

[Example]

```
#include    <stdio.h>
void func(void) {
        int         i, n;
        float       x;
        const char  *s;
        char        name[10];
        s = "23 11.1e-1 NAME";
        n = sscanf(s,"%d%f%s", &i, &x, name);   /*Stores 23 in i, 1.110000 in x, and "NAME"
                                                  in name.  The return value n is 3.*/
}
```

fscanf

Read and interpret data from stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

```
#include <stdio.h>
int fscanf(FILE *stream, const char *format[, arg, ...]);
```

[Return value]

The number of input fields for which scanning, conversion, and storage were executed normally is returned. The return value does not include scanned fields that were not stored. If an attempt is made to read to the end of the file, the return value is EOF. If no field was stored, the return value is 0.

[Description]

Reads the input to be converted according to the format specified by the character string pointed to by *format* from *stream* and treats the *arg* arguments that follow format as objects for storing the converted input. Only the standard input/output stdin can be specified for *stream*. The method of specifying *format* is the same as described for the sscanf function.

scanf

Read and interpret text from standard output stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int scanf(const char **format*[, *arg*, ...]);

[Return value]

The number of input fields for which scanning, conversion, and storage were executed normally is returned. The return value does not include scanned fields that were not stored. If an attempt is made to read to the end of the file, the return value is EOF. If no field was stored, the return value is 0.

[Description]

Reads the input to be converted according to the format specified by the character string pointed to by *format* from the standard input/output stdin and treats the *arg* arguments that follow format as objects for storing the converted input. The method of specifying *format* is the same as described for the sscanf function.

[Example]

```
#include    <stdio.h>
void func(void) {
        int     i, n;
        double  x;
        char    name[10];
        n = scanf("%d%lf%s", &i, &x, name); /*Perform formatted input of input from stdin
                                              using the format "23 11.1e-1 NAME".*/
}
```

ungetc

Push character back to input stream

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

#include <stdio.h>
int ungetc(int *c*, FILE **stream*);

[Return value]

The character *c* is returned.
Error return does not occur.

[Description]

This function pushes the character *c* back into the input stream pointed to by *stream*. However, if *c* is EOF, no pushback is performed. The character *c* that was pushed back will be input as the first character during the next character input. Only one character can be pushed back by ungetc. If ungetc is executed continuously, only the last ungetc will have an effect. Only the standard input/output stdin can be specified for *stream*.

rewind

Reset file position indicator

Remark These functions are not supported by the debugging functions which CubeSuite+ provides.

[Classification]

Standard library

[Syntax]

```
#include <stdio.h>
void    rewind(FILE *stream);
```

[Description]

This function clears the error indicator of the input stream pointed to by *stream*, and positions the file position indicator at the beginning of the file.

However, only the standard input/output stdin can be specified for *stream*. Therefore, rewind only has the effect of discarding the character that was pushed back by ungetc.

perror

Error processing

[Classification]

Standard library

[Syntax]

```
#include <stdio.h>
void    perror(const char *s);
```

[Description]

This function outputs to stderr the error message that corresponds to global variable errno.
The message that is output is as follows.

When *s* is not NULL	`fprintf(stderr, "%s:%s\n", s, s_fix);`
When *s* is NULL	`fprintf(stderr, "%s\n", s_fix);`

s_fix is as follows.

When errno is EDOM	"EDOM error"
When errno is ERANGE	"ERANGE error"
When errno is 0	"no error"
Otherwise	"error *xxx*" (*xxx* is abs (errno) % 1000)

[Example]

```
#include    <stdio.h>
#include    <errno.h>
void func(double x) {
        double  d;
        errno = 0;
        d = exp(x);
        if(errno)
                perror("func1");    /*If a calculation exception is generated by exp perror
                                      is called.*/
}
```

6.4.8 Standard utility functions

Standard Utility functions are as follows.

Table 6-10. Standard Utility Functions

Function/Macro Name	Outline
abs	Output absolute value (int type)
labs	Output absolute value (long type)
llabs	Output absolute value (long long type)
bsearch	Binary search
qsort	Sort
div	Division (int type)
ldiv	Division (long type)
lldiv	Division (long long type)
atoi	Conversion of character string to integer (int type)
atol	Conversion of character string to integer (long type)
atoll	Conversion of character string to integer (long long type)
strtol	Conversion of character string to integer (long type) and storing pointer in last character string
strtoul	Conversion of character string to integer (unsigned long type) and storing pointer in last character string
strtoll	Conversion of character string to integer (long long type) and storing pointer in last character string
strtoull	Conversion of character string to integer (unsigned long long type) and storing pointer in last character string
atoff	Conversion of character string to floating-point number (float type)
atof	Conversion of character string to floating-point number (double type)
strtodf	Conversion of character string to floating-point number (float type) (storing pointer in last character string)
strtod	Conversion of character string to floating-point number (double type) (storing pointer in last character string
calloc	Memory allocation (initialized to zero)
malloc	Memory allocation(not initialized to zero)
realloc	Memory re-allocation
free	Memory release
rand	Pseudorandom number sequence generation
srand	Setting of type of pseudorandom number sequence
abort	Terminates the program

abs

Output absolute value (int type)

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
int abs(int *j*);

[Return value]

Returns the absolute value of *j* (size of *j*), | *j* |.

[Description]

This function obtains the absolute value of *j* (size of *j*), | *j* |. If *j* is a negative number, the result is the reversal of j. If *j* is not negative, the result is *j*.

[Example]

```
#include    <stdlib.h>
void func(int l) {
        int val;
        val = -15;
        l = abs(val);   /*Returns absolute value of val, 15, to 1.*/
}
```

labs

Output absolute value (long type)

[Classification]

Standard library

[Syntax]

```
#include <stdlib.h>
long    labs(long j);
```

[Return value]

Returns the absolute value of *j* (size of *j*), | *j* |.

[Description]

This function obtains the absolute value of *j* (size of *j*), | *j* |. If *j* is a negative number, the result is the reversal of j. If *j* is not negative, the result is *j*. This function is the same as abs, but uses long type instead of int type, and the return value is also of long type.

llabs

Output absolute value (long long type)

[Classification]

Standard library

[Syntax]

```
#include <stdlib.h>
long long      llabs(long long j);
```

[Return value]

Returns the absolute value of *j* (size of *j*), | *j* |.

[Description]

This function obtains the absolute value of *j* (size of *j*), | *j* |. If *j* is a negative number, the result is the reversal of j. If *j* is not negative, the result is *j*. This function is the same as abs, but uses long long type instead of int type, and the return value is also of long long type.

bsearch

Binary search

[Classification]

Standard library

[Syntax]

#include <stdlib.h>

void* bsearch(const void *_key_, const void *_base_, size_t _nmemb_, size_t _size_, int (*_compar_)(const void *, const void*));

[Return value]

A pointer to the element in the array that coincides with *key* is returned. If there are two or more elements that coincide with *key*, the one that has been found first is indicated. If there are not elements that coincide with *key*, a null pointer is returned.

[Description]

This function searches an element that coincides with *key* from an array starting with *base* by means of binary search. *nmemb* is the number of elements of the array. *size* is the size of each element. The array must be arranged in the ascending order in respect to the compare function indicated by *compar* (last argument). Define the compare function indicated by *compar* to have two arguments. If the first argument is less than the second, a negative integer must be returned as the result. If the two arguments coincide, zero must be returned. If the first is greater than the second, a positive integer must be returned.

[Example]

```
#include    <stdlib.h>
#include    <string.h>
int compar(const void *x, const void *y);

void func(void) {
        static  char    *base[] = {"a", "b", "c", "d", "e", "f"};
        char            *key = "c";     /*Search key is "c".*/
        char            **ret;
                                        /*Pointer to "c" is stored in ret.*/
        ret = (char **) bsearch((char *) &key, (char *) base, 6, sizeof(char *), compar);
}
int compar(const void *x, const void *y) {
        return(strcmp(x, y));           /*Returns positive, zero, or negative integer as
                                           result of comparing arguments.*/
}
```

qsort

Sort

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
void qsort(void *base, size_t nmemb, size_t size, int (*compar)(const void*, const void *));

[Description]

This function sorts the array pointed to by *base* into ascending order in relation to the comparison function pointed to by *compar*. *nmemb* is the number of array elements, and *size* is the size of each element. The comparison function pointed to by *compar* is the same as the one described for bsearch.

div

Division (int type)

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
div_t div(int *n*, int *d*);

[Return value]

The structure storing the result of the division is returned.

[Description]

This function is used to divide a value of int type

This function calculates the quotient and remainder resulting from dividing numerator *n* by denominator *d*, and stores these two integers as the members of the following structure div_t.

```
typedef struct {
        int quot;
        int rem;
} div_t;
```

quot the quotient, and rem is the remainder. If *d* is not zero, and if "*r* = div(*n*, *d*);", *n* is a value equal to "*r*.rem + *d* * *r*.quot".

If *d* is zero, the resultant quot member has a sign the same as *n* and has the maximum size that can be expressed. The rem member is 0.

[Example]

```
#include    <stdlib.h>
void func(void) {
        div_t   r;
        r = div(110, 3);    /*36 is stored in r.quot, and 2 is stored in r.rem.*/
}
```

ldiv

Division (long type)

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
ldiv_t ldiv(long *n*, long *d*);

[Return value]

The structure storing the result of the division is returned.

[Description]

This function is used to divide a value of long type.

This function calculates the quotient and remainder resulting from dividing numerator *n* by denominator *d*, and stores these two integers as the members of the following structure div_t.

```
typedef struct {
        long    quot;
        long    rem;
} ldiv_t;
```

quot the quotient, and rem is the remainder. If *d* is not zero, and if "*r* = div(*n*, *d*);", *n* is a value equal to "*r*.rem + *d* * *r*.quot".

If *d* is zero, the resultant quot member has a sign the same as *n* and has the maximum size that can be expressed. The rem member is 0.

lldiv

Division (long long type)

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
lldiv_t lldiv(long long *n*, long long *d*);

[Return value]

The structure storing the result of the division is returned.

[Description]

This function is used to divide a value of long long type.

This function calculates the quotient and remainder resulting from dividing numerator *n* by denominator *d*, and stores these two integers as the members of the following structure div_t.

```
typedef struct {
        long long   quot;
        long long   rem;
} lldiv_t;
```

quot the quotient, and rem is the remainder. If *d* is not zero, and if "*r* = div(*n*, *d*);", *n* is a value equal to "*r*.rem + *d* * *r*.quot".

If *d* is zero, the resultant quot member has a sign the same as *n* and has the maximum size that can be expressed. The rem member is 0.

atoi

Conversion of character string to integer (int type)

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
int atoi(const char *_str_);

[Return value]

Returns the converted value if the partial character string could be converted. If it could not, 0 is returned.

[Description]

This function converts the first part of the character string indicated by *str* into an int type representation. atoi is the same as "(int) strtol (*str*, NULL, 10)".

atol

Conversion of character string to integer (long type)

[Classification]

Standard library

[Syntax]

```
#include <stdlib.h>
long    atol(const char *str);
```

[Return value]

Returns the converted value if the partial character string could be converted. If it could not, 0 is returned.

[Description]

This function converts the first part of the character string indicated by *str* into a long int type representation. atol is the same as "strtol (*str*, NULL, 10)".

atoll

Conversion of character string to integer (long long type)

[Classification]

Standard library

[Syntax]

```
#include <stdlib.h>
long long   atoll(const char *str);
```

[Return value]

Returns the converted value if the partial character string could be converted. If it could not, 0 is returned.

[Description]

This function converts the first part of the character string indicated by *str* into a long long int type representation. atol is the same as "strtol (*str*, NULL, 10)".

strtol

Conversion of character string to integer (long type) and storing pointer in last character string

[Classification]

Standard library

[Syntax]

```
#include <stdlib.h>
long    strtol(const char *str, char **ptr, int base);
```

[Return value]

Returns the converted value if the partial character string could be converted. If it could not, 0 is returned.

If an overflow occurs (because the converted value is too great), LONG_MAX or LONG_MIN is returned, and macro ERANGE is set to global variable errno.

[Description]

This function converts the first part of the character string indicated by *str* into a long type representation. strol first divides the input characters into the following three parts: the "first blank", "a string represented by the *base* number determined by the value of base and is subject to conversion into an integer", and "the last one or more character string that is not recognized (including the null character (\0))". Then strtol converts the string into an integer, and returns the result.

(1) Specify 0 or 2 to 36 as argument *base*.

(a) If *base* is 0

The expected format of the character string subject to conversion is of integer format having an optional + or - sign and "0x", indicating a hexadecimal number, prefixed.

(b) If the value of *base* is 2 to 36

The expected format of the character string is of character string or numeric string type having an optional + or - sign prefixed and expressing an integer whose base is specified by base. Characters "a" (or "A") through "z" (or "Z") are assumed to have a value of 10 to 35. Only characters whose value is less than that of base can be used.

(c) If the value of *base* is 16

"0x" is prefixed (suffixed to the sign if a sign exists) to the string of characters and numerals (this can be omitted).

(2) The string subject to conversion is defined as the longest partial string at the beginning of the input character string that starts with the first character other than blank and has an expected format.

(a) If the input character string is vacant, if it consists of blank only, or if the first character that is not blank is not a sign or a character or numeral that is permitted, the subject string is vacant.

(b) If the string subject to conversion has an expected format and if the value of *base* is 0, the base number is judged from the input character string. The character string led by 0x is regarded as a hexadecimal value, and the character string to which 0 is prefixed but x is not is regarded as an octal number. All the other character strings are regarded as decimal numbers.

(c) If the value of *base* is 2 to 36, it is used as the base number for conversion as mentioned above.

(d) If the string subject to conversion starts with a - sign, the sign of the value resulting from conversion is reversed.

(3) The pointer that indicates the first character string

(a) This is stored in the object indicated by *ptr*, if *ptr* is not a null pointer.

(b) If the string subject conversion is vacant, or if it does not have an expected format, conversion is not executed. The value of *str* is stored in the object indicated by *ptr* if ptr is not a null pointer.

Remark This function is not re-entrant

[Example]

```
#include    <stdlib.h>
void func(long ret) {
        char    *p;
        ret = strtol("10", &p, 0);      /*10 is returned to ret.*/
        ret = strtol("0x10", &p, 0);    /*16 is returned to ret.*/
        ret = strtol("10x", &p, 2);     /*2 is returned to ret, and pointer to "x" is
                                          returned to area of p.*/
        ret = strtol("2ax3", &p, 16);   /*42 is returned to ret, and pointer to "x" is
                                          returned to area of p.*/
          :
}
```

strtoul

Conversion of character string to integer (unsigned long type) and storing pointer in last character string

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
unsigned long strtoul(const char **str*, char ***ptr*, int *base*);

[Return value]

Returns the converted value if the partial character string could be converted. If it could not, 0 is returned.
If an overflow occurs, ULONG_MAX is returned, and macro ERANGE is set to global variable errno.

[Description]

This function is the same as strtol except that the type of the return value is of unsigned long type.

strtoll

Conversion of character string to integer (long long type) and storing pointer in last character string

[Classification]

Standard library

[Syntax]

#include <stdlib.h>

long long strtoll(const char **str*, char ***ptr*, int *base*);

[Return value]

Returns the converted value if the partial character string could be converted. If it could not, 0 is returned.

If an overflow occurs (the converted value is too larger), LLONG_MAX or LLONG_MIN is returned, and macro ERANGE is set to global variable errno.

[Description]

This function is the same as strtol except that the type of the return value is of long long type.

strtoull

Conversion of character string to integer (unsigned long long type) and storing pointer in last character string

[Classification]

Standard library

[Syntax]

#include <stdlib.h>

unsigned long long strtoull(const char **str*, char ***ptr*, int *base*);

[Return value]

Returns the converted value if the partial character string could be converted. If it could not, 0 is returned.

If an overflow occurs, ULLONG_MAX is returned, and macro ERANGE is set to global variable errno.

[Description]

This function is the same as strtol except that the type of the return value is of unsigned long long type.

atoff

Conversion of character string to floating-point number (float type)

[Classification]

Standard library

[Syntax]

```
#include <stdlib.h>
float   atoff(const char *str);
```

[Return value]

If the partial character string has been converted, the resultant value is returned. If the character string could not be converted, 0 is returned.

If an overflow occurs (the value is not in the range in which it can be expressed), HUGE_VAL or -HUGE_VAL is returned, and ERANGE is set to global variable errno. If an underflow occurs, 0 is returned, and macro ERANGE is set to global variable errno.

[Description]

This function converts the first portion of the character string indicated by *str* into a float type representation. atoff is the same as "strtodf (*str*, NULL)".

atof

Conversion of character string to floating-point number (double type)

[Classification]

Standard library

[Syntax]

```
#include <stdlib.h>
double  atof(const char *str);
```

[Return value]

If the partial character string has been converted, the resultant value is returned. If the character string could not be converted, 0 is returned.

If an overflow occurs (the value is not in the range in which it can be expressed), HUGE_VAL or -HUGE_VAL is returned, and ERANGE is set to global variable errno. If an underflow occurs, 0 is returned, and macro ERANGE is set to global variable errno.

[Description]

This function converts the first portion of the character string indicated by *str* into a float type representation. atoff is the same as "strtod (*str*, NULL)".

strtodf

Conversion of character string to floating-point number (float type) (storing pointer in last character string)

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
float strtodf(const char **str*, char ***ptr*);

[Return value]

If the partial character string has been converted, the resultant value is returned. If the character string could not be converted, 0 is returned. If an overflow occurs (the value is not in the range in which it can be expressed), HUGE_VAL or -HUGE_VAL is returned, and ERANGE is set to global variable errno. If an underflow occurs, 0 is returned, and macro ERANGE is set to global variable errno.

[Description]

This function converts the first part of the character string indicated by *str* into a float type representation. The part of the character string to be converted is in the following format and is at the beginning of *str* with the maximum length, starting with a normal character that is not a space.

[+ | -] digits [.] [digits] [(e | E) [+ | -] digits]

If *str* is vacant or consists of space characters only, if the first normal character is other than "+", "-", ".", or a numeral, the partial character string does not include a character. If the partial character string is vacant, conversion is not executed, and the value of str is stored in the area indicated by *ptr*. If the partial character string is not vacant, it is converted, and a pointer to the last character string (including the null character (\0) indicating at least the end of str) is stored in the area indicated by *ptr*.

Remark This function is not re-entrant.

[Example]

```
#include    <stdlib.h>
#include    <stdio.h>
void func(float ret) {
        char    *p, *str, s[30];
        str = "+5.32a4e";
        ret = strtodf(str, &p);         /*5.320000 is returned to ret, and pointer to "a"
                                          is stored in area of p.*/
        sprintf(s, "%lf\t%c", ret, *p); /*"5.320000 a" is stored in array indicated by s.*/
}
```

strtod

Conversion of character string to floating-point number (double type) (storing pointer in last character string)

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
double strtod(const char **str*, char ***ptr*);

[Return value]

If the partial character string has been converted, the resultant value is returned. If the character string could not be converted, 0 is returned.

If an overflow occurs (the value is not in the range in which it can be expressed), HUGE_VAL or -HUGE_VAL is returned, and ERANGE is set to global variable errno. If an underflow occurs, 0 is returned, and macro ERANGE is set to global variable errno.

[Description]

This function converts the first part of the character string indicated by *str* into a float type representation. The part of the character string to be converted is in the following format and is at the beginning of *str* with the maximum length, starting with a normal character that is not a space.

[+ | -] digits [.] [digits] [(e | E) [+ | -] digits]

If *str* is vacant or consists of space characters only, if the first normal character is other than "+", "-", ".", or a numeral, the partial character string does not include a character. If the partial character string is vacant, conversion is not executed, and the value of str is stored in the area indicated by *ptr*. If the partial character string is not vacant, it is converted, and a pointer to the last character string (including the null character (\0) indicating at least the end of str) is stored in the area indicated by *ptr*.

Remark This function is not re-entrant.

calloc

Memory allocation (initialized to zero)

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
void *calloc(size_t *nmemb*, size_t *size*);

[Return value]

When area allocation succeeds, a pointer to that area is returned. When the area could not be allocated, a null pointer is returned.

[Description]

This function allocates an area for an array of *nmemb* elements. The allocated area is initialized to zeros.

[Caution]

The memory area management functions automatically allocate memory area as necessary from the heap memory area.

Also, the size of the default is 0x1000 bytes, so when it's changed, the heap memory area must be allocated. The area allocation should be performed first by an application.

[Heap memory setup example]

```
#include    <stddef.h>
#define     SIZEOF_HEAP 0x1000
int     _REL_sysheap[SIZEOF_HEAP >> 2];
size_t  _REL_sizeof_sysheap = SIZEOF_HEAP;
```

Remarks 1. The variable "_REL_sysheap" points to the starting address of heap memory. This value must be a multiple of 4.

2. The required heap memory size (bytes) should be set for the variable "_REL_sizeof_sysheap".

[Example]

```
#include    <stdlib.h>
typedef struct {
        double  d[3];
        int     i[2];
} s_data;
int func(void) {
        sdata   *buf;
        if((buf = calloc(40, sizeof(s_data))) == NULL)  /*allocate an area for 40 s_data*/
                return(1);
           :
        free(buf);                                      /*release the area*/
        return(0);
}
```

malloc

Memory allocation(not initialized to zero)

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
void *malloc(size_t *size*);

[Return value]

When area allocation succeeds, a pointer to that area is returned. When the area could not be allocated, a null pointer is returned.

[Description]

This function allocates an area having a size indicated by *size*. The area is not initialized.

[Caution]

The memory area management functions automatically allocate memory area as necessary from the heap memory area.

Also, the size of the default is 0x1000 bytes, so when it's changed, the heap memory area must be allocated. The area allocation should be performed first by an application.

[Heap memory setup example]

```
#include    <stddef.h>
#define     SIZEOF_HEAP 0x1000
int     _REL_sysheap[SIZEOF_HEAP >> 2];
size_t  _REL_sizeof_sysheap = SIZEOF_HEAP;
```

Remarks 1. The variable "_REL_sysheap" points to the starting address of heap memory. This value must be a multiple of 4.

2. The required heap memory size (bytes) should be set for the variable "_REL_sizeof_sysheap".

realloc

Memory re-allocation

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
void *realloc(void **ptr*, size_t *size*);

[Return value]

When area allocation succeeds, a pointer to that area is returned. When the area could not be allocated, a null pointer is returned.

[Description]

This function changes the size of the area pointed to by *ptr* to the size indicated by *size*. The contents of the area are unchanged up to the smaller of the previous size and the specified *size*. If the area is expanded, the contents of the area greater than the previous size are not initialized. When *ptr* is a null pointer, the operation is the same as that of malloc (*size*). Otherwise, the area that was acquired by calloc, malloc, or realloc must be specified for *ptr*.

[Caution]

The memory area management functions automatically allocate memory area as necessary from the heap memory area.

Also, the size of the default is 0x1000 bytes, so when it's changed, the heap memory area must be allocated. The area allocation should be performed first by an application.

[Heap memory setup example]

```
#include    <stddef.h>
#define     SIZEOF_HEAP 0x1000
int     _REL_sysheap[SIZEOF_HEAP >> 2];
size_t  _REL_sizeof_sysheap = SIZEOF_HEAP;
```

Remarks 1. The variable "_REL_sysheap" points to the starting address of heap memory. This value must be a multiple of 4.

2. The required heap memory size (bytes) should be set for the variable "_REL_sizeof_sysheap".

free

Memory release

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
void free(void *ptr);

[Description]

This function releases the area pointed to by *ptr* so that this area is subsequently available for allocation. The area that was acquired by calloc, malloc, or realloc must be specified for *ptr*.

[Example]

```
#include    <stdlib.h>
typedef struct {
        double  d[3];
        int     i[2];
} s_data;
int func(void) {
        sdata   *buf;
        if((buf = calloc(40, sizeof(s_data))) == NULL)  /*allocate an area for 40 s_data*/
                return(1);
           :
        free(buf);                                      /*release the area*/
        return(0);
}
```

rand

Pseudorandom number sequence generation

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
int rand(void);

[Return value]

Random numbers are returned.

[Description]

This function returns a random number that is greater than or equal to zero and less than or equal to RAND_MAX.

[Example]

```
#include    <stdlib.h>
void func(void) {
        if((rand() & 0xF) < 4)
                func1();    /*execute func1 with a probability of 25%*/
}
```

srand

Setting of type of pseudorandom number sequence

[Classification]

Standard library

[Syntax]

```
#include <stdlib.h>
void    srand(unsigned int seed);
```

[Description]

This function assigns seed as the new pseudo random number sequence *seed* to be used by the rand call that follows. If srand is called using the same *seed* value, the same numbers in the same order will appear for the random numbers that are obtained by rand. If rand is executed without executing srand, the results will be the same as when srand(1) was first executed.

abort

Terminates the program

[Classification]

Standard library

[Syntax]

#include <stdlib.h>
void abort(void);

[Description]

Calling abort(void) terminates the program. An abort function that suits the user system must be created in advance.

[Example]

```
#include    <assert.h>
int func(void);
int main() {
    int ret;
    ret = func();
    if (ret == 0) {
    abort();        <- abort() is called if ret is not 0
    }
    return 0;
}
```

6.4.9 Non-local jump functions

Non-local jump functions are as follows.

Table 6-11. Non-Local Jump Functions

Function/Macro Name	Outline
longjmp	Non-local jump
setjmp	Set destination of non-local jump

longjmp

Non-local jump

[Classification]

Standard library

[Syntax]

#include <setjmp.h>
void longjmp(jmp_buf *env*, int *val*);

[Description]

This function performs a non-local jump to the place immediately after setjmp using *env* saved by setjmp. *val* as a return value for setjmp.

[Definition of jmp_buf type in setjmp.h]

```
typedef int     jmp_buf[14];
```

[Caution]

When this function is called, only data in the registers reserved by the compiler are saved and restored.
If setjmp is called from within a function in the 22-register mode or common-register mode, data in r20 to r24 are destroyed from within a function in the 32-register mode, and longjmp is then called, the values of r20 to r24 will not be recoverable. In such cases, the values of r20 to r24 must be restored before longjmp is called if they are required.
When -Xep=fix is specified, ep/fix/libsetjmp.lib must be used.

[Example]

```
#include    <setjmp.h>
#define ERR_XXX1    1
#define ERR_XXX2    2

jmp_buf jmp_env;

void main(void) {
    for(;;) {
        switch(setjmp(jmp_env)) {
            case    ERR_XXX1:
                /*termination of error XXX1*/
                break;
            case    ERR_XXX2:
                /*termination of error XXX2*/
                break;
            case    0:          /*no non-local jumps*/
            default:
                break;
        }
    }
}

void funcXXX(void) {
    longjmp(jmp_env, ERR_XXX1); /*Non-local jumps are performed upon generation of
                                  error XXX1.*/
    longjmp(jmp_env, ERR_XXX2); /*Non-local jumps are performed upon generation of
                                  error XXX2.*/
}
```

setjmp

Set destination of non-local jump

[Classification]

Standard library

[Syntax]

#include <setjmp.h>
int setjmp(jmp_buf *env*);

[Return value]

Calling setjmp returns 0. When longjmp is used for a non-local jump, the return value is in the second parameter, val. However, 1 is returned if *val* is 0.

[Description]

This function sets *env* as the destination for a non-local jump. In addition, the environment in which setjmp was run is saved to *env*.

[Definition of jmp_buf type in setjmp.h]

```
typedef int     jmp_buf[14];
```

[Caution]

When this function is called, only data in the registers reserved by the compiler are saved and restored.

If setjmp is called from within a function in the 22-register mode or common-register mode, data in r20 to r24 are destroyed from within a function in the 32-register mode, and longjmp is then called, the values of r20 to r24 will not be recoverable. In such cases, the values of r20 to r24 must be restored before longjmp is called if they are required.

When -Xep=fix is specified, ep/fix/libsetjmp.lib must be used.

6.4.10 Mathematical functions

Mathematical functions are as follows.

Table 6-12. Mathematical Functions

Function/Macro Name	Outline
expf	Exponent function
exp	Exponent function
logf	Logarithmic function (natural logarithm)
log	Logarithmic function (natural logarithm)
log10f	Logarithmic function (base = 10)
log10	Logarithmic function (base = 10)
powf	Power function
pow	Power function
sqrtf	Square root function
sqrt	Square root function
ceilf	ceiling function
ceil	ceiling function
fabsf	Absolute value function
fabs	Absolute value function
floorf	floor function
floor	floor function
fmodf	Remainder function
fmod	Remainder function
frexpf	Divide floating-point number into mantissa and power
frexp	Divide floating-point number into mantissa and power
ldexpf	Convert floating-point number to power
ldexp	Convert floating-point number to power
modff	Divide floating-point number into integer and decimal
modf	Divide floating-point number into integer and decimal
cosf	Cosine
cos	Cosine
sinf	Sine
sin	Sine
tanf	Tangent
tan	Tangent
acosf	Arc cosine
acos	Arc cosine
asinf	Arc sine
asin	Arc sine

Function/Macro Name	Outline
atanf	Arc tangent
atan	Arc tangent
atan2f	Arc tangent (y / x)
atan2	Arc tangent (y / x)
coshf	Hyperbolic cosine
cosh	Hyperbolic cosine
sinhf	Hyperbolic sine
sinh	Hyperbolic sine
tanhf	Hyperbolic tangent
tanh	Hyperbolic tangent

expf

Exponent function

[Classification]

Mathematical library

[Syntax]

```
#include <mathf.h>
float   expf(float x);
```

[Return value]

Returns the *x*th power of e.

expf returns an denormal number if an underflow occurs (if *x* is a negative number that cannot express the result), and sets macro ERANGE to global variable errno. If an overflow occurs (if *x* is too great a number), HUGE_VAL (maximum double type numerics that can be expressed) is returned, and macro ERANGE is set to global variable errno.

[Description]

This function calculates the *x*th power of e (e is the base of a natural logarithm and is about 2.71828).

exp

Exponent function

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double exp(double *x*);

[Return value]

Returns the *x*th power of e.

expf returns an denormal number if an underflow occurs (if *x* is a negative number that cannot express the result), and sets macro ERANGE to global variable errno. If an overflow occurs (if *x* is too great a number), HUGE_VAL (maximum double type numerics that can be expressed) is returned, and macro ERANGE is set to global variable errno.

[Description]

This function calculates the *x*th power of e (e is the base of a natural logarithm and is about 2.71828).

logf

Logarithmic function (natural logarithm)

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float logf(float *x*);

[Return value]

Returns the natural logarithm of *x*.
logf returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno if *x* is negative. If *x* is zero, it returns -∞ and sets macro ERANGE to global variable errno.

[Description]

This function calculates the natural logarithm of *x*, i.e., logarithm with base e.

log

Logarithmic function (natural logarithm)

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double log(double *x*);

[Return value]

Returns the natural logarithm of *x*.
logf returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno if *x* is negative. If *x* is zero, it returns -∞ and sets macro ERANGE to global variable errno.

[Description]

This function calculates the natural logarithm of *x*, i.e., logarithm with base e.

log10f

Logarithmic function (base = 10)

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float log10f(float *x*);

[Return value]

Returns the logarithm of *x* with base 10.
log10f returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno if *x* is negative. If *x* is zero, it returns -∞ and sets macro ERANGE to global variable errno.

[Description]

This function calculates the logarithm of *x* with base 10. This is realized by "log (*x*) / log (10)".

log10

Logarithmic function (base = 10)

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double log10(double *x*);

[Return value]

Returns the logarithm of *x* with base 10.
log10f returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno if *x* is negative. If *x* is zero, it returns -∞ and sets macro ERANGE to global variable errno.

[Description]

This function calculates the logarithm of *x* with base 10. This is realized by "log (*x*) / log (10)".

powf

Power function

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float powf(float *x*, float *y*);

[Return value]

Returns the *y*th power of *x*.

powf returns a negative solution only if *x* < 0 and *y* is an odd integer. If *x* < 0 and *y* is a non-integer or if *x* = *y* = 0, powf returns a Not a Nuber(NaN) and sets the macro EDOM for the global variable errno. If *x* = 0 and *y* < 0 or if an overflow occurs, powf returns ±HUGE_VAL and sets the macro ERANGE for errno. If the solution vanished approaching zero, powf returns 0 and sets the macro ERANGE for errno. If the solution is a denormal number, powf sets the macro ERANGE for errno.

[Description]

This function calculates the *y*th power of *x*.

[Example]

```
#include    <mathf.h>
float func(void) {
        float   ret, x, y;
        ret = powf(x, y);   /*Returns yth power of x to ret.*/
          :
        return(ret);
}
```

pow

Power function

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double pow(double *x*, double *y*);

[Return value]

Returns the *y*th power of *x*.

powf returns a negative solution only if $x < 0$ and *y* is an odd integer. If $x < 0$ and *y* is a non-integer or if $x = y = 0$, powf returns a Not a Nuber(NaN) and sets the macro EDOM for the global variable errno. If $x = 0$ and $y < 0$ or if an overflow occurs, powf returns ±HUGE_VAL and sets the macro ERANGE for errno. If the solution vanished approaching zero, powf returns 0 and sets the macro ERANGE for errno. If the solution is a denormal number, powf sets the macro ERANGE for errno.

[Description]

This function calculates the *y*th power of *x*.

sqrtf

Square root function

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float sqrtf(float *x*);

[Return value]

Returns the positive square root of *x*.
sqrtf returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno if *x* is a negative real number.

[Description]

This function calculates the square root of *x*.

sqrt

Square root function

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double sqrt(double *x*);

[Return value]

Returns the positive square root of *x*.
sqrtf returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno if *x* is a negative real number.

[Description]

This function calculates the square root of *x*.

ceilf

ceiling function

[Classification]

Mathematical library

[Syntax]

```
#include <mathf.h>
float   ceilf(float x);
```

[Return value]

Returns the minimum integer greater than *x* and *x*.

[Description]

This function calculates the minimum integer value greater than *x* and *x*.

ceil

ceiling function

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double ceil(double *x*);

[Return value]

Returns the minimum integer greater than *x* and *x*.

[Description]

This function calculates the minimum integer value greater than *x* and *x*.

fabsf

Absolute value function

[Classification]

Mathematical library

[Syntax]

```
#include <mathf.h>
float   fabsf(float x);
```

[Return value]

Returns the absolute value (size) of *x*.

[Description]

This function calculates the absolute value (size) of *x* by directly manipulating the bit representation of *x*.

fabs

Absolute value function

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double fabs(double *x*);

[Return value]

Returns the absolute value (size) of *x*.

[Description]

This function calculates the absolute value (size) of *x* by directly manipulating the bit representation of *x*.

floorf

floor function

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float floorf(float *x*);

[Return value]

Returns the maximum integer value less than *x* and *x.*

[Description]

This function calculates the maximum integer value less than *x* and *x*.

floor

floor function

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double floor(double *x*);

[Return value]

Returns the maximum integer value less than *x* and *x.*

[Description]

This function calculates the maximum integer value less than *x* and *x*.

fmodf

Remainder function

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float fmodf(float *x*, float *y*);

[Return value]

Returns a floating-point value that is the remainder resulting from dividing *x* by *y*.
If *y* is ±∞, fmodf returns *x*.
If *x* is ±∞ or *y* is zero, fmodf returns a Not a Nuber(NaN) and sets macro ERANGE to global variable errno.

[Description]

This function calculates a floating-point value that is the remainder resulting from dividing *x* by *y*. In other words, it calculates the value "*x* - i * *y*" for the maximum integer i that has a sign the same as *x* and is less than *y*, if *y* is not zero.

[Example]

```
#include    <mathf.h>
void func(void) {
        float   ret, x, y;
        ret = fmodf(x, y);  /*Returns remainder resulting from dividing x by y to ret.*/
          :
}
```

fmod

Remainder function

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double fmod(double *x*, double *y*);

[Return value]

Returns a floating-point value that is the remainder resulting from dividing *x* by *y*.
If *y* is ±∞, fmod returns *x*.
If *x* is ±∞ or *y* is zero, fmod returns a Not a Nuber(NaN) and sets macro ERANGE to global variable errno.

[Description]

This function calculates a floating-point value that is the remainder resulting from dividing *x* by *y*. In other words, it calculates the value "*x* - i * *y*" for the maximum integer i that has a sign the same as *x* and is less than *y*, if *y* is not zero.

frexpf

Divide floating-point number into mantissa and power

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float frexpf(float *val*, int **exp*);

[Return value]

Returns mantissa m.
frexpf sets 0 to **exp* and returns 0 if *val* is 0.
If *val* is ±∞, frexpf returns zero and sets macro EDOM to global variable errno.

[Description]

This function expresses *val* of float type as mantissa m and the pth power of 2. The resulting mantissa m is 0.5 <= | x | < 1.0, unless *val* is zero. p is stored in **exp*. m and p are calculated so that *val* = m * 2^{p}.

[Example]

```
#include    <mathf.h>
void func(void) {
        float   ret, x;
        int     exp;
        x = 5.28;
        ret = frexpf(x, &exp);  /*Resultant mantissa 0.66 is returned to ret, and 3 is
                                  stored in exp.*/
          :
}
```

frexp

Divide floating-point number into mantissa and power

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double frexp(double *val*, int **exp*);

[Return value]

Returns mantissa m.
frexpf sets 0 to **exp* and returns 0 if *val* is 0.
If *val* is ±∞, frexpf returns zero and sets macro EDOM to global variable errno.

[Description]

This function expresses *val* of double type as mantissa m and the pth power of 2. The resulting mantissa m is 0.5 <= | x | < 1.0, unless *val* is zero. p is stored in **exp*. m and p are calculated so that *val* = m * 2^{p}.

ldexpf

Convert floating-point number to power

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>

float ldexpf(float *val*, int *exp*);

[Return value]

Returns the value calculated by*val* x 2 ^{exp}.

If an underflow or overflow occurs as a result of executing ldexpf, macro ERANGE is set to global variable errno. If an underflow occurs, ldexpf returns an denormal number. If an overflow occurs, it returns HUGE_VAL.

[Description]

This function calculates *val* x 2 ^{exp}.

ldexp

Convert floating-point number to power

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double ldexp(double *val*, int *exp*);

[Return value]

Returns the value calculated by$val \times 2^{exp}$.
If an underflow or overflow occurs as a result of executing ldexpf, macro ERANGE is set to global variable errno. If an underflow occurs, ldexpf returns an denormal number. If an overflow occurs, it returns HUGE_VAL.

[Description]

This function calculates $val \times 2^{exp}$.

modff

Divide floating-point number into integer and decimal

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float modff(float *val*, float **ipart*);

[Return value]

Returns a decimal part. The sign of the result is the same as the sign of *val*.

[Description]

This function divides *val* of float type into integer and decimal parts, and stores the integer part in **ipart*. Rounding is not performed. It is guaranteed that the sum of the integer part and decimal part accurately coincides with *val*. For example, where *realpart* = modff (*val*, *&intpart*), "*realpart* + *intpart*t" coincides with *val*.

modf

Divide floating-point number into integer and decimal

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double modf(double *val*, double **ipart*);

[Return value]

Returns a decimal part. The sign of the result is the same as the sign of *val*.

[Description]

This function divides *val* of double type into integer and decimal parts, and stores the integer part in **ipart*. Rounding is not performed. It is guaranteed that the sum of the integer part and decimal part accurately coincides with *val*. For example, where *realpart* = modff (*val*, *&intpart*), "*realpart* + *intpart*t" coincides with *val*.

cosf

Cosine

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float cosf(float *x*);

[Return value]

Returns the cosine of *x*.
If inputting ±∞, cosf returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno.

[Description]

This function calculates the cosine of *x*. Specify the angle in radian.

cos

Cosine

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double cos(double *x*);

[Return value]

Returns the cosine of *x*.
If inputting ±∞, cos returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno.

[Description]

This function calculates the cosine of *x*. Specify the angle in radian.

sinf

Sine

[Classification]

Mathematical library

[Syntax]

```
#include <mathf.h>
float   sinf(float x);
```

[Return value]

Returns the sine of *x*.
If inputting ±∞, sinf returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno.
If the solution is a denormal number, sinf sets macro ERANGE to global variable errno.

[Description]

This function calculates the sine of *x*. Specify the angle in radian.

sin

Sine

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double sin(double *x*);

[Return value]

Returns the sine of *x*.
If inputting ±∞, sin returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno.
If the solution is a denormal number, sin sets macro ERANGE to global variable errno.

[Description]

This function calculates the sine of *x*. Specify the angle in radian.

tanf

Tangent

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float tanf(float *x*);

[Return value]

Returns the tangent of *x*.
If inputting ±∞, tanf returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno.
If the solution is a denormal number, tanf sets macro ERANGE to global variable errno.

[Description]

This function calculates the cosine of *x*. Specify the angle in radian.

tan

Tangent

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double tan(double *x*);

[Return value]

Returns the tangent of *x*.
If inputting ±∞, tan returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno.
If the solution is a denormal number, tan sets macro ERANGE to global variable errno.

[Description]

This function calculates the cosine of *x*. Specify the angle in radian.

acosf

Arc cosine

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float acosf(float *x*);

[Return value]

Returns the arc cosine of *x*. The returned value is in radian and in a range of 0 to π.
If *x* is not between -1 and 1, a Not a Nuber(NaN) is returned, and macro EDOM is set to global variable errno.

[Description]

This function calculates the arc cosine of *x*. Specify *x* as, -1<= *x* <= 1.

acos

Arc cosine

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double acos(double *x*);

[Return value]

Returns the arc cosine of *x*. The returned value is in radian and in a range of 0 to π.
If *x* is not between -1 and 1, a Not a Nuber(NaN) is returned, and macro EDOM is set to global variable errno.

[Description]

This function calculates the arc cosine of *x*. Specify *x* as, -1<= *x* <= 1.

asinf

Arc sine

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float asinf(float *x*);

[Return value]

Returns the arc sine (arcsine) of *x*. The returned value is in radian and in a range of -π / 2 to π / 2.
If *x* is not between -1 and 1, a Not a Nuber(NaN) is returned, and macro EDOM is set to global variable errno.

[Description]

This function calculates the arc sine (arcsine) of *x*. Specify *x* as, -1 <= *x* <= 1.

asin

Arc sine

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double asin(double *x*);

[Return value]

Returns the arc sine (arcsine) of *x*. The returned value is in radian and in a range of -π / 2 to π / 2.
If *x* is not between -1 and 1, a Not a Nuber(NaN) is returned, and macro EDOM is set to global variable errno.

[Description]

This function calculates the arc sine (arcsine) of *x*. Specify *x* as, -1 <= *x* <= 1.

atanf

Arc tangent

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float atanf(float *x*);

[Return value]

Returns the arc tangent (arctangent) of *x*. The returned value is in radian and in a range of -π / 2 to π / 2.
If the solution is a denormal number, atanf sets macro ERANGE to global variable errno.

[Description]

This function calculates the arc tangent (arctangent) of *x*. Specify *x* as, -1 <= *x* <= 1.

[Example]

```
#include    <mathf.h>
float func(float x) {
        float   ret;
        ret = atanf(x); /*Returns value of arctangent of x to ret.*/
          :
        return(ret);
}
```

atan

Arc tangent

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double atan(double *x*);

[Return value]

Returns the arc tangent (arctangent) of *x*. The returned value is in radian and in a range of -π / 2 to π / 2.
If the solution is a denormal number, atan sets macro ERANGE to global variable errno.

[Description]

This function calculates the arc tangent (arctangent) of *x*. Specify *x* as, -1 <= *x* <= 1.

atan2f

Arc tangent (y / x)

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float atan2f(float *y*, float *x*);

[Return value]

Returns the arc tangent (arctangent) of *y* / *x*. The returned value is in radian and in a range of -π to π.

atan2f returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno if both *x* and *y* are 0.0. If the solution vanished approaching zero, atan2f returns ±0 and sets macro ERANGE to global variable errno. If the solution is a denormal number, atan2f sets macro ERANGE to global variable errno.

[Description]

This function calculates the arc tangent of *y* / *x*. atan2f calculates the correct result even if the angle is in the vicinity of π / 2 or - π / 2 (if *x* is close to 0).

atan2

Arc tangent (y / x)

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double atan2(double *y*, double *x*);

[Return value]

Returns the arc tangent (arctangent) of *y* / *x*. The returned value is in radian and in a range of -π to π.

atan2f returns a Not a Nuber(NaN) and sets macro EDOM to global variable errno if both *x* and *y* are 0.0. If the solution vanished approaching zero, atan2f returns ±0 and sets macro ERANGE to global variable errno. If the solution is a denormal number, atan2f sets macro ERANGE to global variable errno.

[Description]

This function calculates the arc tangent of *y* / *x*. atan2f calculates the correct result even if the angle is in the vicinity of π / 2 or - π / 2 (if *x* is close to 0).

coshf

Hyperbolic cosine

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float coshf(float *x*);

[Return value]

Returns the hyperbolic cosine of *x*.
coshf returns HUGE_VAL and sets macro ERANGE to global variable errno if an overflow occurs.

[Description]

This function calculates the hyperbolic cosine of *x*. Specify the angle in radian. The definition expression is as follows.

$$(e^{x} + e^{-x}) / 2$$

[Example]

```
#include    <mathf.h>
float func(float x) {
        float   ret;
        ret = coshf(x);     /*Returns value of hyperbolic cosine of x to ret.*/
          :
        return(ret);
}
```

cosh

Hyperbolic cosine

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double cosh(double *x*);

[Return value]

Returns the hyperbolic cosine of *x*.
coshf returns HUGE_VAL and sets macro ERANGE to global variable errno if an overflow occurs.

[Description]

This function calculates the hyperbolic cosine of *x*. Specify the angle in radian. The definition expression is as follows.

$$(e^{x} + e^{-x}) / 2$$

sinhf

Hyperbolic sine

[Classification]

Mathematical library

[Syntax]

#include <mathf.h>
float sinhf(float *x*);

[Return value]

Returns the hyperbolic sine of *x*.
sinhf returns HUGE_VAL and sets macro ERANGE to global variable errno if an overflow occurs.

[Description]

This function calculates the hyperbolic sine of *x*. Specify the angle in radian. The definition expression is as follows.

$$(e^{x} - e^{-x}) / 2$$

sinh

Hyperbolic sine

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double sinh(double *x*);

[Return value]

Returns the hyperbolic sine of *x*.
sinhf returns HUGE_VAL and sets macro ERANGE to global variable errno if an overflow occurs.

[Description]

This function calculates the hyperbolic sine of *x*. Specify the angle in radian. The definition expression is as follows.

$$(e^{x} - e^{-x}) / 2$$

tanhf

Hyperbolic tangent

[Classification]

Mathematical library

[Syntax]

```
#include <math.h>
float   tanhf(float x);
```

[Return value]

Returns the hyperbolic tangent of *x*.
If the solution is a denormal number, tanhf sets macro ERANGE to global variable errno.

[Description]

This function calculates the hyperbolic tangent of *x*. Specify the angle in radian. The definition expression is as follows.

$$\sinh(x) / \cosh(x)$$

tanh

Hyperbolic tangent

[Classification]

Mathematical library

[Syntax]

#include <math.h>
double tanh(double *x*);

[Return value]

Returns the hyperbolic tangent of *x*.
If the solution is a denormal number, tanh sets macro ERANGE to global variable errno.

[Description]

This function calculates the hyperbolic tangent of *x*. Specify the angle in radian. The definition expression is as follows.

sinh (*x*) / cosh (*x*)

6.4.11 RAM section initialization function

RAM section initialization function are as follows.

Table 6-13. RAM Section Initialization Function

Function/Macro Name	Outline
_INITSCT_RH	Copies initial values to or clears sections in RAM

_INITSCT_RH

Copies initial values to or clears sections in RAM

[Classification]

Standard library

[Syntax]

#include <_h_c_lib.h>
void _INITSCT_RH(void * datatbl_start, void * datatbl_end, void * bsstbl_start, void * bsstbl_end)

[Argument(s)/Return value]

Argument	Return Value
datatbl_start : First address of the initialization table for a section with the data attribute datatbl_end: Last address of the initialization table for a section with the data attribute bsstbl_start : First address of the initialization table for a section with the bss attribute bsstbl_end: Last address of the initialization table for a section with the bss attribute	None

[Description]

For sections in RAM, this function copies initial values for a section with the data attribute from the ROM area and clears a section with the bss attribute to 0.

The first and second parameters are used to pass the first and last addresses of the initialization table for a section with the data attribute.

The third and fourth parameters are used to pass the first and last addresses of the initialization table for a section with the bss attribute.

If the value of the first parameter is greater than or equal to that of the second parameter, the section with the data attribute is not initialized.

If the value of the third parameter is greater than or equal to that of the fourth parameter, the section with the bss attribute is not cleared to zero.

[Example]

```
struct {
    void *rom_s;    //The first address of the section with the data attribute in the ROM
    void *rom_e;    //The last address of the section with the data attribute in the ROM
    void *ram_s;    //The first address of the section with the data attribute in the RAM
} _C_DSEC[M];

struct {
    void *bss_s;    //The first address of the section with the bss attribute in the RAM
    void *bss_e;    //The last address of the section with the bss attribute in the RAM
} _C_BSEC[N];

_INITSCT_RH(_C_DSEC, _C_DSEC + M, _C_BSEC, _C_BSEC + N);
```

Remark When the start address of the .bss section is 0x100 and the size of the section is 0x50 bytes, the memory addresses that are actually cleared to 0 are 0x100, 0x101, ..., 0x14e, and 0x14f but specify addresses 0x100 and 0x150 in the initialization table.

6.4.12 Initialization peripheral devices function

Initialization peripheral devices function are as follows.

Table 6-14. Initialization Peripheral Devices Function

Function/Macro Name	Outline
hdwinit	Initialization of peripheral devices immediately after the CPU reset

hdwinit

Initialization of peripheral devices immediately after the CPU reset.

[Classification]

Standard library

[Syntax]

```
void    hdwinit(void);
```

[Description]

The initialization peripheral devices function performs initialization of peripheral devices immediately after the CPU reset.

This is called from inside the startup routine.

The function included in the library is a dummy routine that performs no actions; code a function in accordance with your system.

6.4.13 Operation runtime functions

Operation runtime functions are as follows.

Table 6-15. Operation Runtime Functions

Classification	Function Name	Outline
float type operation function	_COM_fadd	Addition of single-precision floating-point
	_COM_fsub	Subtraction of single-precision floating-point
	_COM_fmul	Multiplication of single-precision floating-point
	_COM_fdiv	Division of single-precision floating-point
double type operation function	_COM_dadd	Addition of double-precision floating-point
	_COM_dsub	Subtraction of double-precision floating-point
	_COM_dmul	Multiplication of double-precision floating-point
	_COM_ddiv	Division of double-precision floating-point
long long type operation function	_COM_mul64	Multiplication of 64-bit integer
	_COM_div64	Division of signed 64-bit integer
	_COM_udiv64	Division of unsigned 64-bit integer
	_COM_rem64	Remainder of signed 64-bit integer
	_COM_urem64	Remainder of unsigned 64-bit integer
	_COM_shll_64_32	Logical left shift of 64-bit integer
	_COM_shrl_64_32	Logical right shift of 64-bit integer
	_COM_shra_64_32	Arithmetic right shift 64-bit integer
	_COM_neg64	Sign inversion

Classification	Function Name	Outline
Type conversion function	_COM_itof	Conversion from 32-bit integer to single-precision floating-point number
	_COM_itod	Conversion from 32-bit integer to double-precision floating-point number
	_COM_utof	Conversion from unsigned 32-bit integer to single-precision floating-point number
	_COM_utod	Conversion from unsigned 32-bit integer to double-precision floating-point number
	_COM_i64tof	Conversion from 64-bit integer to single-precision floating-point number
	_COM_i64tod	Conversion from 64-bit integer to double-precision floating-point number
	_COM_u64tof	Conversion from unsigned 64-bit integer to single-precision floating-point number
	_COM_u64tod	Conversion from unsigned 64-bit integer to double-precision floating-point number
	_COM_ftoi	Conversion from single-precision floating-point number to 32-bit integer
	_COM_dtoi	Conversion from double-precision floating-point number to 32-bit integer
	_COM_ftou	Conversion from single-precision floating-point number to unsigned 32-bit integer
	_COM_dtou	Conversion from double-precision floating-point number to unsigned 32-bit integer
	_COM_ftoi64	Conversion from single-precision floating-point number to 64-bit integer
	_COM_dtoi64	Conversion from double-precision floating-point number to 64-bit integer
	_COM_ftou64	Conversion from single-precision floating-point number to unsigned 64-bit integer
	_COM_dtou64	Conversion from double-precision floating-point number to unsigned 64-bit integer
	_COM_ftod	Conversion from single-precision floating-point number to double-precision floating-point number
	_COM_dtof	Conversion from double-precision floating-point number to single-precision floating-point number
Floating-point comparison functions	_COM_fgt	Comparison
	_COM_fge	Comparison
	_COM_feq	Comparison
	_COM_fne	Comparison
	_COM_flt	Comparison
	_COM_fle	Comparison
	_COM_funord	Incomparable
	_COM_dgt	Comparison
	_COM_dge	Comparison
	_COM_deq	Comparison
	_COM_dne	Comparison
	_COM_dlt	Comparison
	_COM_dle	Comparison
	_COM_dunord	Incomparable

CHAPTER 7 STARTUP

This chapter explains the startup.

7.1 Outline

The startup processing is used to initialize a section for embedding the user application described with the C language to the system or start the main function.

This section assumes two types of programs: a program for a single core device which uses only the single core, and a program for a multi-core device which uses multiple cores.

The program for a single core device uses one application project only.

The program for a multi-core device provides one boot loader project and the required number of application projects.

The following shows the configuration of the basic startup routine to operate those programs, using examples of R7F701Z07 and R7F701352AFP.

7.2 Startup Routine

Startup routine is the routine that is to be executed after microcontroller is reset and before the execution of main function. Basically, it carries out the initialization after system is reset.

Here describes the following:

- Exception vector table
- Startup routine for the boot loader project
- Startup routine for the application project
- Passing information from the application project to the boot loader project

When a new project is created on CubeSuite+, the following sample files are automatically registered in the file nodes of the project tree according to the type of the project.

- boot.asm/vecttbl.asm (boot loader for a multi-core device (CC-RH))
- cstartm.asm (application for a multi-core device (CC-RH))
- cstart.asm (application (CC-RH))

Those sample files are explained below.

7.2.1 Exception vector table

A branch destination for the case of reset of the microcontroller or generation of other exceptions is specified for the exception vector table.

The exception vector table is described in vecttbl.asm in the sample program and referenced from the following projects.

For a program for a single core device: application project

For a program for a multi-core device: boot loader project

vecttbl.asm is configured by the following elements.

- RESET vector
- Interrupt handler table
- Exception handler routine

(1) RESET vector

A branch instruction to the entry point routine, which is common to the processor element (PE), is allocated to the address where a branch of the program counter occurs when the microcontroller is started and reset.

In the sample program, the branch instruction is allocated to the RESET section. The section name is optionally changeable but needed be changed in conjunction with the -start option of the optimizing linker.

```
-start=RESET/01000000
```

Caution For the address of the RESET vectors, see the user's manual of the device.

The EBASE register is handled that holds the same value as the RBASE register and shares the exception vector table including the RESET vector. A branch instruction to exception handler addresses of the standard specification (direct vector method) is allocated in the RESET section.
When the RBASE register is operated similarly with the EBASE register regardless of the state of the PSW.EBV register, the following description is required in the startup routine.

```
stsr    2, r10, 1       ; get RBASE
ldsr    r10, 3, 1       ; set EBASE
```

Remark The initial state of the device is PSW.EBV = 0; it is not necessary because EBASE is not used.

The RBASE and EBASE registers, which hold addresses, hold an address in the unit of 512 bytes; the top of the RESET section is aligned at the 512-byte boundary.

Caution For the alignment address or the number of vectors of the RESET section, see the user's manual of the device.

(2) Interrupt handler table

When an exception handler address of the extended specification (table lookup method) is used, the address of the exception handler routine is allocated to the corresponding element position on this table.
In the sample program, the address is allocated to the EIINTTBL section. The section name is optionally changeable but needed be changed in conjunction with the processing of the INTBP register setting in the startup.

```
mov     #__sEIINTTBL, r10
ldsr    r10, 4, 1               ; set INTBP
```

The INTBP register, which holds table addresses, holds an address in the unit of 512 bytes; the top of the EIINTTBL section is aligned at the 512-byte boundary.

Caution For the maximum number of elements in the table, see the user's manual of the device.

(3) Exception handler routine

The sample program for the exception handler routine of FE and EI levels repeats branches to itself without any operation. Usually, it uses #pragma interrupt with the C source description.

7.2.2 Startup routine for the boot loader project

The startup routine for the boot loader project is used in a program for a multi-core device and configured with two files: boot.asm and vecttbl.asm (Exception vector table).

boot.asm is configured by the following elements.

- Processing required for a program for a multi-core device

- Entry routine common to PE
- __exit routine
- Entry routine for PE1
- Entry routine for PE3

- Processing prepared as required
  - hdwinit_PE1 routine
  - hdwinit_PE3 routine
  - zeroclr4 routine
  - init_eiint routine

(1) Entry routine common to PE

Each PE commonly executes processing. The PE reads its processor element number (PEID) and branches to entry routines prepared for each PEID. If the PE has no application, the branches converge to the __exit routine just below the entry routine.

(2) __exit routine

The __exit routine repeats branches to itself to put PEs that is not used to sleep.

(3) Entry routine for PE1

Branches to the application project for PE1 are performed with the following procedure.

(a) Call the hardware initialization routine for PE1, hdwinit_PE1().

(b) Call the EI-level exception setting routine, init_eiint(). It is disabled in the sample program; enable the USE_TABLE_REFERENCE_METHOD macro at the top of the file.

Remark Refer to the description of hdwinit_PE1 routine and init_eiint routine explained later. If processing is not required, the routine needs not be called.

(c) Set PC via the FEPC register.

Read the address of the entry routine for the application project from the application information table created in the application project.

(d) Branch to the entry routine of the application. Execute the feret instruction to reflect the above FEPC register value to PC and branch to the entry routine in the application.

(4) Entry routine for PE3

The PE3 entry routine has basically same configuration as the PE1 entry routine, however, in the sample program, it ends processing at the branch to __exit routine, not to the application.

(5) hdwinit_PE1 routine

The following procedure is used for one initialization in the hardware and initialization specific to PE1.

(a) Initialize Global RAM and Local RMA (PE1) for the ECC function. In the sample program, the address range for R7F701Z07 is specified and initialized via Local RAM (self).

Caution For the RAM addresses to be initialized, see the user's manual of the device.

(b) Wait for the end of initialization of PE3. The following shows the procedure.

The mutual exclusion variable (MEV) is used as the flag for waiting processing. In boot.asm, MEV is operated by a macro "MEV_ADDR" which has the MEV address as a value.

- The mutual exclusion variable (MEV) is prepared and initialized by 0.
- Set 1 to bit 0 in MEV which indicates the end of processing of PE1 itself.
- Check the value of bit 1 in MEV which indicates the end of processing of PE3.
- If bit 1 in MEV is 1, the initialization processing of PE1 and PE3 has ended and the program exits the wait processing. If bit 1 is 0, PE3 is in the initialization processing and the program returns to the second processing to continue the wait processing.

Remarks 1. If synchronization is not needed in PE1 and PE3, this processing is not required.

2. The countermeasure for ECC error is taken by continuing the processing for setting 1 to bit 0 after MEV is initialized to 0. The Global RAM for allocating MEV needs not be initialized because it is initialized by PE1 itself, however, initialization is performed to keep the symmetry with PE3.

(6) hdwinit_PE3 routine

The following procedure is used for initialization specific to PE3.

(a) Initialize Local RMA (PE3) for the ECC function. In the sample program, the address range for R7F701Z07 is specified and initialized via Local RAM (self).

Caution For the RAM addresses to be initialized, see the user's manual of the device.

(b) Wait for the end of initialization of PE1. The following shows the procedure.

- Similarly to PE1, the mutual exclusion variable (MEV) is initialized to 0.
- Set 1 to bit 1 in MEV which indicates the end of processing of PE3 itself.
- Check the value of bit 0 in MEV which indicates the end of processing of PE1.
- If bit 0 in MEV is 1, the initialization processing of PE1 and PE3 has ended and the program exits the wait processing. If bit 0 is 0, PE1 is in the initialization processing and the program returns to the second processing to continue the wait processing.

(7) zeroclr4 routine

The zerocir4 routine has the ECC function to initialize each RAM. The address ranges passed from the r6 and r7 registers are cleared to 0.

Caution For the memory to be initialized and the initialization method, see the user's manual of the device.

(8) init_eiint routine

The init_eiint routine is a subroutine that initializes the EI-level exception. The following processing is performed.

- Set the start address of the EIINTTBL section to the INTBP register.
- In the sample program, use the interrupt control register to set the branch methods for some EI-level exceptions to the extended specification (table lookup method). If the exception handler for the extended specification is not used, the setting is not required.

It is disabled in the sample program; enable the USE_TABLE_REFERENCE_METHOD macro at the top of the file.

Caution For the interrupt control register, see the user's manual of the device

7.2.3 Startup routine for the application project

The startup routine for the application project sets initialization in the unit of application required for executing the user application (after the main function).

- In the program for a single core device, two files (vecttbl.asm and cstart.asm) are prepared.
- In the program for a multi-core device, cstart.asm is prepared for each application project.
  vecttbl.asm is only prepared for the boot loader project.

vecttbl.asm (Exception vector table) is configured by the following elements.

- RESET vector
- Interrupt handler table
- Exception handler routine

Remark For setting information other than that passed from the application project to the boot loader project, both of label names and section names can be overlapped between application projects. To avoid confusion due to overlapping, when a section name specific to each project is used, specify the -Xmulti_level=1 option of the compiler and use #pragma pmodule on the C source program.

cstart.asm is configured by the following elements.

- Stack area
- RAM section initialization table
- Entry routine
- Processing routine branching to the user application
- abort routine
- hdwinit routine
- zeroclr4 routine
- init_eiint routine
- Application information table

(1) Stack area

The stack area is used for the compiler generation code.
In the sample program, the stack area is reserved for the .stack.bss section of the bss attribute.

Remark When the stack area is reserved for other than the .bss section, there are two purposes: one is that the user variable area and the allocated position are distinguished, and the other is that the program startup time is reduced because initialization can be omitted in the C language specification.

When the memory is referenced by stack pointer (sp) relative in CC-RH, a code is output assuming that sp is allocated in the 4-byte boundary and the stack area is made to be grown to the direction of the 0x0 address. Therefore, the edge of the 0xffffffff address side of the .stack.bss section must be aligned at the 4-byte boundary.

(2) RAM section initialization table

When an external variable is used in the C source program, the area must be initialized before executing the program.
Initialization is performed in the unit of section where external variables are allocated, and the start and end labels of the section generated by a optimizing linker
When the section has the initial value, a line is configured as "#__s section name, #__e section name, #__s initialization-destination section name", as shown below, and the lines are allocated for the required number of sections.
There are following rules in the initialization table for the section with the initial value.

- The initialization table must be allocated to the .INIT_DSEC.const section, and the section name is fixed.

- Only the initialization table can be allocated.
- The start of the initialization table must be aligned at the 4-byte boundary.

```
.section    ".INIT_DSEC.const", const
.align      4
.dw         #__s.data, #__e.data, #__s.data.R
.dw         #__s.sdata, #__e.sdata, #__s.sdata.R
```

To generate the initialization-destination section, the -rom option of the optimizing linker is used.

```
-rom=.data=.data.R
-rom=.sdata=.sdata.R
```

When the section without initial value, a line is configured as "#__s section name, #__e section name", as shown below, and the lines are allocated for the required number of sections.
There are following rules in the initialization table for the section without initial value.

- The initialization table must be allocated to the .INIT_BSEC.const section, and the section name is fixed.
- Only the initialization table can be allocated.
- The start of the initialization table must be aligned at the 4-byte boundary.

```
.section    ".INIT_BSEC.const", const
.align      4
.dw         #__s.bss, #__e.bss
.dw         #__s.sbss, #__e.sbss
```

When the sections described in those tables do not exist in the user application, an error occurs at linking. To avoid this, the empty dummy section as shown below is prepared for the section name described in the table.

```
        .section    ".data", data
.L.dummy.data:
        .section    ".sdata", sdata
.L.dummy.sdata:
        .section    ".bss", bss
.L.dummy.bss:
        .section    ".sbss", sbss
.L.dummy.sbss:
```

When #pragma pmodule is used in the program for a multi-core device, the section name is automatically modified and all the section names that can be appeared are described.

```
        .section    ".INIT_DSEC.const", const
        .align      4
        .dw         #__s.data.pm1, #__e.data.pm1, #__s.data.pm1.R
        .dw         #__s.data.cmn, #__e.data.cmn, #__s.data.cmn.R
        .dw         #__s.data, #__e.data, #__s.data.R
        .dw         #__s.sdata.pm1, #__e.sdata.pm1, #__s.sdata.pm1.R
        .dw         #__s.sdata.cmn, #__e.sdata.cmn, #__s.sdata.cmn.R
```

```
        .dw         #__s.sdata, #__e.sdata, #__s.sdata.R

        .section    ".INIT_BSEC.const", const
        .align      4
        .dw         #__s.bss.pm1, #__e.bss.pm1
        .dw         #__s.bss.cmn, #__e.bss.cmn
        .dw         #__s.bss, #__e.bss
        .dw         #__s.sbss.pm1, #__e.sbss.pm1
        .dw         #__s.sbss.cmn, #__e.sbss.cmn
        .dw         #__s.sbss, #__e.sbss

        .section    ".data.pm1", data
.L.dummy.data.pm1:
        .section    ".data.cmn", data
.L.dummy.data.cmn:
        .section    ".data", data
.L.dummy.data:
        .section    ".sdata.pm1", sdata

.L.dummy.data.pm1:
        .section    ".sdata.cmn", sdata
.L.dummy.data.cmn:
        .section    ".sdata", sdata
.L.dummy.data:

        .section    ".bss.pm1", bss
.L.dummy.bss.pm1:
        .section    ".bss.cmn", bss
.L.dummy.bss.cmn:
        .section    ".bss", bss
.L.dummy.bss:

        .section    ".sbss.pm1", sbss
.L.dummy.bss.pm1:
        .section    ".sbss.cmn", sbss
.L.dummy.bss.cmn:
        .section    ".sbss", sbss
.L.dummy.sbss:
```

Remark When the contents of the .INIT_DSEC.const and .INIT_BSEC.const sections are sufficient, no dummy sections are required.

(3) Entry routine

The execution environment (PE) is initialized with the following procedure.

(a) Set the most significant address of the stack area to the sp (r3) register. The set value must be a multiple of 4.

(b) Set the address of the __gp_data label to the gp (r4) register. The __gp_data label is automatically generated by a optimizing linker when the gp relative section is in use.

(c) Set the address of the __ep_data label to the ep (r30) register. The __ep_data label is automatically generated by a optimizing linker when the ep relative section is in use.

Remark When the gp relative and ep relative sections are not in use in the program, even if there are setting codes for gp and ep, it is only redundant and no problem occurs.

(d) Call hdwinit() and make specific initialization to PE.
The same initialization is allowed in the boot loader project; initialization based on the data defined in the application side is performed in the application project side, and initialization by the data shared between PEs is performed in the boot loader project side.

(e) Call __INITSCT_RH to initialize the RAM section.

- When both sections with or without initial values are initialized:

```
mov     #__s.INIT_DSEC.const, r6
mov     #__e.INIT_DSEC.const, r7
mov     #__s.INIT_BSEC.const, r8
mov     #__e.INIT_BSEC.const, r9
jarl    __INITSCT_RH, lp
```

- When only the section with initial values is initialized:

```
mov     #__s.INIT_DSEC.const, r6
mov     #__e.INIT_DSEC.const, r7
mov     r0, r8
mov     r0, r9
jarl    __INITSCT_RH, lp
```

- When only the section without initial values is initialized:

```
mov     r0, r6
mov     r0, r7
mov     #__s.INIT_BSEC.const, r8
mov     #__e.INIT_BSEC.const, r9
jarl    __INITSCT_RH, lp
```

(f) Branch to the processing that branches to the user application.

(4) Processing routine branching to the user application

Branches to the user application are performed with the following procedure.

(a) Set PSW and the branch destination to branch to the user application via the FEPSW register.
In the sample program, the following settings are made.

Target Program	FPU	EI-level Exception	User Mode
Program for a single core device (for R7F701352AFP)	OFF	OFF	OFF
Program for a multi-core device (for R7F701Z07)	ON	OFF	ON

(b) Set the start address (#_main) of the user application to the FEPC register.

(c) Execute the feret instruction to reflect the PSW setting and branch to the user application.

Remark When the operating mode of the CPU is not changed, a branch instruction, not the feret instruction, is available.

```
jarl32  #_main, lp
```

(5) abort routine

The abort routine is required when the assert macro or abort itself is used in the user application. In the sample program, branching to the abort routine itself is only repeated.

(6) hdwinit routine

In the sample program for a single core device, a Local RAM is initialized for the ECC function.

Caution The sample program specifies the address range for R7F701354AFP.
See the user's manual of the device and specify the appropriate address.

(7) zeroclr4 routine

The zerocir4 routine has the ECC function to initialize each RAM. The address ranges passed from the r6 and r7 registers are cleared to 0.

Caution For the memory to be initialized and the initialization method, see the user's manual of the device.

(8) init_eiint routine

The init_eiint routine is a subroutine that initializes the EI-level exception. The following processing is performed.

- Set the start address of the EIINTTBL section to the INTBP register.
- In the sample program, use the interrupt control register to set the branch methods for some EI-level exceptions to the extended specification (table lookup method). If the exception handler for the extended specification is not used, the setting is not required.

It is disabled in the sample program; enable the USE_TABLE_REFERENCE_METHOD macro at the top of the file.

Caution For the interrupt control register, see the user's manual of the device.

(9) Application information table

The application information table stores context information that is passed to the boot loader project in the program for a multi-core device.

In the sample program, the following information is stored in the table.

Offset	Value	Remark
0	Entry routine address of the application	Specifies the absolute address of the label corresponding to __start

The section name for allocating a table is .const.cmn. The label in this section is referenced from the boot loader project.

Caution When the startup routine is copied between application projects, the label names in .const.cmn must be changed so that they are not overlapped.

Remark The application information table can be changed as required. To change this table, the table in the boot loader project side must also be read.

7.2.4 Passing information from the application project to the boot loader project

A program for a multi-core device is configured of the boot loader project and multiple application projects.

The -fsymbol option of the optimizing linker is used in the boot loader project to initialize hardware or use the information set in each application project. Accordingly, the public label name in the specified section and information of the address value after linking can be output to the file (symbol address file) using an option and passed to the boot loader project.

The following shows an example for passing the entry routine address from the application project to the boot loader project.

To reference the address of __start_pm1 from the boot loader project, specify __start_pm1 with public.

```
;; cstart.asm
        .section    ".text.cmn", text
        .public     __start_pm1
__start_pm1:
        jarl        _main, lp
```

When the application project is linked, the -fsymbol option specifies the .text.cmn section where the __start_pm1 label exists. In this case, the pm1.fsy file is generated.

```
>rlink cstart.obj .opm1.abs -fsymbol=.text.cmn
```

The boot loader project references __start_pm1.

```
;; boot.asm
        .section    ".text", text
__start:
        cmp         1, r6
        bnz         .L1
        jr32        #__start_pm1
.L1:
```

When the fsy file generated from each application project is compiled with the boot loader project, the address value in the .fsy file resolves references in boot.asm.

```
>ccrh boot.asm pm1.fsy pm2.fsy -oboot.abs
```

Caution All the public labels in the section specified with the -fsymbol option are considered to have been defined in the boot loader project. Therefore, if there are labels with the same name in the specified sections of different application projects, a multiple definition error will occur at linking in the boot loader side (even if the section names are the same between applications, they will not collide). Note that many labels must not be defined in the section specified for the fsymbol option in the application project; if defined, the label name must be the one that will not collide with other application projects.

7.3 Coding Example

The following is an example of exception vector table.

Table 7-1. Examples of exception vector table

```
        .section        "RESET", text
        .align  512
        jr32    __start         ; RESET

        .align  16
        jr32    _Dummy          ; SYSERR

        .align  16
        jr32    _Dummy          ; HVTRAP

        .align  16
        jr32    _Dummy          ; FETRAP

        .align  16
        jr32    _Dummy_EI       ; TRAP0

        .align  16
        jr32    _Dummy_EI       ; TRAP1

        .align  16
        jr32    _Dummy          ; RIE

        .align  16
        jr32    _Dummy_EI       ; FPP/FPI

        .align  16
        jr32    _Dummy          ; UCPOP

        .align  16
```

```
        jr32    _Dummy          ; MIP/MDP/ITLBE/DTLBE

        .align  16
        jr32    _Dummy          ; PIE

        .align  16
        jr32    _Dummy          ; Debug

        .align  16
        jr32    _Dummy          ; MAE

        .align  16
        jr32    _Dummy          ; (R.F.U)

        .align  16
        jr32    _Dummy          ; FENMI

        .align  16
        jr32    _Dummy          ; FEINT

        .align  16
        jr32    _Dummy_EI       ; INTn(priority0)

        .align  16
        jr32    _Dummy_EI       ; INTn(priority1)

        .align  16
        jr32    _Dummy_EI       ; INTn(priority2)

        .align  16
        jr32    _Dummy_EI       ; INTn(priority3)

        .align  16
        jr32    _Dummy_EI       ; INTn(priority4)

        .align  16
        jr32    _Dummy_EI       ; INTn(priority5)

        .align  16
        jr32    _Dummy_EI       ; INTn(priority6)

        .align  16
        jr32    _Dummy_EI       ; INTn(priority7)

        .section        "EIINTTBL", const
```

```
        .align  512
        .dw     #_Dummy_EI      ; INT0
        .dw     #_Dummy_EI      ; INT1
        .dw     #_Dummy_EI      ; INT2
        .rept   288 - 3
        .dw     #_Dummy_EI      ; INTn
        .endm

        .section        ".text", text
        .align  2
_Dummy:
        br      _Dummy

_Dummy_EI:
        br      _Dummy_EI
```

The following is an example of startup routine of a project for a single core device.

Table 7-2. Examples of startup routine of a project for a single core device

```
; NOTE : THIS IS A TYPICAL EXAMPLE. (R7F701352AFP)

        ; example of using eiint as table refrence method
        ;USE_TABLE_REFERENCE_METHOD .set 1

;---------------------------------------------------------------------------
;       system stack
;---------------------------------------------------------------------------
STACKSIZE           .set    0x200
        .section    "stack.bss", bss
        .align      4
        .ds         (STACKSIZE)
        .align      4
.stacktop:

;---------------------------------------------------------------------------
;       section initialize table
;---------------------------------------------------------------------------
        .section    ".INIT_DSEC.const", const
        .align      4
        .dw         #__s.data, #__e.data, #__s.data.R

        .section    ".INIT_BSEC.const", const
        .align      4
        .dw         #__s.bss, #__e.bss
```

```
;-------------------------------------------------------------------------------
;       startup
;-------------------------------------------------------------------------------
        .section    ".text", text
        .public     __start
        .align      2
__start:
        mov         #_stacktop, sp          ; set sp register
        mov         #__gp_data, gp          ; set gp register
        mov         #__ep_data, ep          ; set ep register

        jarl        _hdwinit, lp            ; initialize hardware

        mov         #__s.INIT_DSEC.const, r6
        mov         #__e.INIT_DSEC.const, r7
        mov         #__s.INIT_BSEC.const, r8
        mov         #__e.INIT_BSEC.const, r9
        jarl32      __INITSCT_RH, lp        ; initialize RAM area

$ifdef USE_TABLE_REFERENCE_METHOD
        jarl        _init_eiint, lp         ; initialize exception
$endif

        ; set various flags to PSW via FEPSW
        stsr        5, r10, 0               ; r10 <- PSW

        ;xori       0x0020, r10, r10        ; enable interrupt

        ;movhi      0x4000, r0, r11
            ;or          r11, r10           ; supervisor mode -> user mode

        ldsr        r10, 3, 0               ; FEPSW <- r10

        mov         #_exit, lp              ; lp <- #_exit
        mov         #_main, r10
        ldsr        r10, 2, 0               ; FEPC <- #_main

        ; apply PSW and call main
        feret
_exit:
        br          _exit                   ; end of program

;-------------------------------------------------------------------------------
;      abort
```

```
;-------------------------------------------------------------------------------
        .public     _abort
        .align      2
_abort:
        br          _abort

;-------------------------------------------------------------------------------
;       target dependence informations (specify values suitable to your system)
;-------------------------------------------------------------------------------
        ; RAM address
        PRIMARY_LOCAL_RAM_ADDR      .set    0xfede0000
        PRIMARY_LOCAL_RAM_END       .set    0xfedfffff

        SECONDARY_LOCAL_RAM_ADDR    .set    0xfedd8000
        SECONDARY_LOCAL_RAM_END     .set    0xfeddffff

        RETENTION_RAM_ADDR          .set    0xfee00000
        RETENTION_RAM_END           .set    0xfee07fff

;-------------------------------------------------------------------------------
;       hdwinit
;-------------------------------------------------------------------------------
        .section    ".text", text
        .align      2
_hdwinit:
        mov         lp, r14                 ; save return address

        mov         PRIMARY_LOCAL_RAM_ADDR, r6
        mov         PRIMARY_LOCAL_RAM_END, r7
        jarl        _zeroclr4, lp           ; clear Primary local RAM

        mov         SECONDARY_LOCAL_RAM_ADDR, r6
        mov         SECONDARY_LOCAL_RAM_END, r7
        jarl        _zeroclr4, lp           ; clear Secondary local RAM

        mov         RETENTION_RAM_ADDR, r6
        mov         RETENTION_RAM_END, r7
        jarl        _zeroclr4, lp           ; clear Retention RAM

        mov         r14, lp
        jmp         [lp]

;-------------------------------------------------------------------------------
;       zeroclr4
;-------------------------------------------------------------------------------
```

```
        .align      2
_zeroclr4:
        br          .L.zeroclr4.2
.L.zeroclr4.1:
        st.w        r0, [r6]
        add         4, r6
.L.zeroclr4.2:
        cmp         r6, r7
        bh          .L.zeroclr4.1
        jmp         [lp]

$ifdef USE_TABLE_REFERENCE_METHOD
;-------------------------------------------------------------------------------
;       init_eiint
;-------------------------------------------------------------------------------
        ; interrupt control register address
        ICBASE                      .set    0xffff9000
        .align      2
_init_eiint:
        mov         #__sEIINTTBL, r10
        ldsr        r10, 4, 1               ; set INTBP
        ; some inetrrupt channels use the table reference method.
        mov         ICBASE, r10             ; get interrupt control register address
        set1        6, 0[r10]               ; set INT0 as table reference
        set1        6, 2[r10]               ; set INT1 as table reference
        set1        6, 4[r10]               ; set INT2 as table reference
        jmp         [lp]
$endif

;-------------------------------------------------------------------------------
;       dummy section
;-------------------------------------------------------------------------------
        .section    ".data", data
.L.dummy.data:
        .section    ".bss", bss
.L.dummy.bss:
        .section    ".const", const
.L.dummy.const:
        .section    ".text", text
.L.dummy.text:
;-------------------- end of start up module -------------------;
```

The following is an example of startup routine of a boot loader project for a multi-core device.

Table 7-3. Examples of startup routine of a boot loader project for a multi-core device

```
; NOTE  : THIS IS A TYPICAL EXAMPLE. (R7F701Z07)

        ; example of using eiint as table reference method
        ;USE_TABLE_REFERENCE_METHOD .set 1

        ; offset of processing module setting table element
        .OFFSET_ENTRY       .set    0

;-------------------------------------------------------------------------------
;       startup
;-------------------------------------------------------------------------------
        .section    ".text", text
        .public     __start
        .align      2
__start:
        ; jump to entry point of each PE
        stsr        0, r10, 2               ; get HTCFG0
        shr         16, r10                 ; get PEID

        cmp         1, r10
        bz          __start_PE1
        cmp         3, r10
        bz          __start_PE3
__exit:
        br          __exit

__start_PE1:
        jarl        _hdwinit_PE1, lp        ; initialize hardware
$ifdef USE_TABLE_REFERENCE_METHOD
        jarl        _init_eiint, lp         ; initialize exception
$endif

        mov         #_pm1_setting_table, r13
        ld.w        .OFFSET_ENTRY[r13], r10 ; r10 <- #__start
        ldsr        r10, 2, 0               ; set FEPC

        ; apply PSW and jump to the application entry point
        feret

__start_PE3:
        jarl        _hdwinit_PE3, lp        ; initialize hardware
$ifdef USE_TABLE_REFERENCE_METHOD
```

```
        jarl        _init_eiint, lp         ; initialize exception
$endif
        ;mov        #_pm2_setting_table, r13
        ;ld.w       .OFFSET_ENTRY[r13], r10 ; r10 <- #__start
        ;ldsr       r10, 2, 0               ; set FEPC

        ; apply PSW and jump to the application entry point
        ;feret
        br          __exit

;-------------------------------------------------------------------------------
;       target dependence informations (specify values suitable to your system)
;-------------------------------------------------------------------------------
$if 1
        ; RAM address
        GLOBAL_RAM_ADDR             .set    0xfeef0000
        GLOBAL_RAM_END              .set    0xfef1ffff

        LOCAL_RAM_PE1_ADDR          .set    0xfedf0000
        LOCAL_RAM_PE1_END           .set    0xfedfffff

        LOCAL_RAM_PE3_ADDR          .set    0xfedf8000
        LOCAL_RAM_PE3_END           .set    0xfedfffff

        ; mutual exclusion variable
        MEV_ADDR                    .set    0xfeef0000

;-------------------------------------------------------------------------------
;       hdwinit_PE1
;-------------------------------------------------------------------------------
        .section    ".text", text
        .align      2
_hdwinit_PE1:
        mov         lp, r14                 ; save return address

        ; clear Global RAM
        mov         GLOBAL_RAM_ADDR, r6
        mov         GLOBAL_RAM_END, r7
        jarl        _zeroclr4, lp

        ; clear Local RAM PE1
        mov         LOCAL_RAM_PE1_ADDR, r6
        mov         LOCAL_RAM_PE1_END, r7
        jarl        _zeroclr4, lp

        ; wait for PE3
```

```
        mov         MEV_ADDR, r10
        st.w        r0, [r10]
.L.hdwinit_PE1.1:
        snooze
        set1        0, [r10]
        tst1        1, [r10]
        bz          .L.hdwinit_PE1.1

        mov         r14, lp
        jmp         [lp]

;-------------------------------------------------------------------------------
;       hdwinit_PE3
;-------------------------------------------------------------------------------
        .section    ".text", text
        .align      2
_hdwinit_PE3:
        mov         lp, r14                 ; save return address

        ; clear Local RAM PE3
        mov         LOCAL_RAM_PE3_ADDR, r6
        mov         LOCAL_RAM_PE3_END, r7
        jarl        _zeroclr4, lp

        ; wait for PE1
        mov         MEV_ADDR, r10
        st.w        r0, [r10]
.L.hdwinit_PE3.1:
        snooze
        set1        1, [r10]
        tst1        0, [r10]
        bz          .L.hdwinit_PE3.1

        mov         r14, lp
        jmp         [lp]

;-------------------------------------------------------------------------------
;       zeroclr4
;-------------------------------------------------------------------------------
        .align      2
_zeroclr4:
        br          .L.zeroclr4.2
.L.zeroclr4.1:
        st.w        r0, [r6]
        add         4, r6
```

```
.L.zeroclr4.2:
        cmp         r6, r7
        bh          .L.zeroclr4.1
        jmp         [lp]
$endif

$ifdef USE_TABLE_REFERENCE_METHOD
;---------------------------------------------------------------------------
;       init_eiint
;---------------------------------------------------------------------------
        ; interrupt control register address
        ICBASE .set 0xfffeea00

        .align 2
_init_eiint:
        mov         #__sEIINTTBL, r10
        ldsr        r10, 4, 1               ; set INTBP

        ; some inetrrupt channels use the table reference method.
        mov         ICBASE, r10             ; get interrupt control register address
        set1        6, 0[r10]               ; set INT0 as table reference
        set1        6, 2[r10]               ; set INT1 as table reference
        set1        6, 4[r10]               ; set INT2 as table reference

        jmp         [lp]
$endif
;-------------------- end of start up module -------------------;
```

The following is an example of startup routine of an application project for a multi-core device.

Table 7-4. Examples of startup routine of an application project for a multi-core device

```
; NOTE  : THIS IS A TYPICAL EXAMPLE. (R7F701Z07)

;---------------------------------------------------------------------------
;       processing module setting table
;---------------------------------------------------------------------------
        .section    ".const.cmn", const
        .public     _pm1_setting_table
        .align      4
_pm1_setting_table:
        .dw         #__start                ; ENTRY ADDRESS

;---------------------------------------------------------------------------
;       system stack
```

```
;-------------------------------------------------------------------------------
        STACKSIZE                   .set    0x200
        .section    ".stack.bss", bss
        .align      4
        .ds         (STACKSIZE)
        .align      4
_stacktop:

;-------------------------------------------------------------------------------
;       section initialize table
;-------------------------------------------------------------------------------
        .section    ".INIT_DSEC.const", const
        .align      4
        .dw         #__s.data, #__e.data, #__s.data.R

        .section    ".INIT_BSEC.const", const
        .align      4
        .dw         #__s.bss, #__e.bss

;-------------------------------------------------------------------------------
;       startup
;-------------------------------------------------------------------------------
        .section    ".text", text
        .public     __start
        .align      2
__start:
        mov         #_stacktop, sp          ; set sp register
        mov         #__gp_data, gp          ; set gp register
        mov         #__ep_data, ep          ; set ep register

        jarl        _hdwinit, lp            ; initialize hardware

        mov         #__s.INIT_DSEC.const, r6
        mov         #__e.INIT_DSEC.const, r7
        mov         #__s.INIT_BSEC.const, r8
        mov         #__e.INIT_BSEC.const, r9
        jarl32      __INITSCT_RH, lp        ; initialize RAM area

        ; set various flags to PSW via FEPSW

        stsr        5, r10, 0               ; r10 <- PSW

        movhi       0x0001, r0, r11
        or          r11, r10                ; enable FPU
```

```
        ;xori       0x0020, r10, r10        ; enable interrupt

        movhi       0x4000, r0, r11
        or          r11, r10                ; supervisor mode -> user mode

        ldsr        r10, 3, 0               ; FEPSW <- r10

        mov         #_exit, lp              ; lp <- #_exit
        mov         #_main, r10
        ldsr        r10, 2, 0               ; FEPC <- #_main

        ; apply PSW and PC to start user mode
        feret

_exit:
        br          _exit                   ; end of program

;-------------------------------------------------------------------------------
;       abort
;-------------------------------------------------------------------------------
        .public     _abort
        .align      2
_abort:
        br          _abort

;-------------------------------------------------------------------------------
;       dummy section
;-------------------------------------------------------------------------------
        .section    ".data", data
.L.dummy.data:
        .section    ".bss", bss
.L.dummy.bss:
        .section    ".const", const
.L.dummy.const:
        .section    ".text", text
.L.dummy.text:
;------------------- end of start up module -------------------;
```

7.4 Symbols

The CC-RH uses the following pointers for operation of applications.

- Global pointer (gp)
- Element pointer (ep)

This section describes the role of each pointer and how pointer values are determined.

7.4.1 Global pointer (gp)

Data that is globally declared in an application is allocated to memory. When referencing (loading or storing) this data that has been allocated to memory, the global pointer (gp) is provided to enable access independent of the allocation position (PID: Position Independent Data).

(1) Setting the global pointer (gp)

Set the value of the global pointer symbol (gp symbol) as the address set in the global pointer (gp).

- The gp symbol is handled as the constant symbol name "__gp_data".
- Declare the gp symbol as a reference symbol (.extern) in the startup routine.
- rlink creates an externally defined symbol (.public) and determines the address of the gp symbol.
- The operations for defining and referencing the gp symbol are as follows.

(a) If there is only an ".extern" declaration of the gp symbol

rlink creates the definition information and sets the address automatically.

(b) If the gp symbol is defined

The defined address is used.

(c) If there is no gp symbol (it is not used)

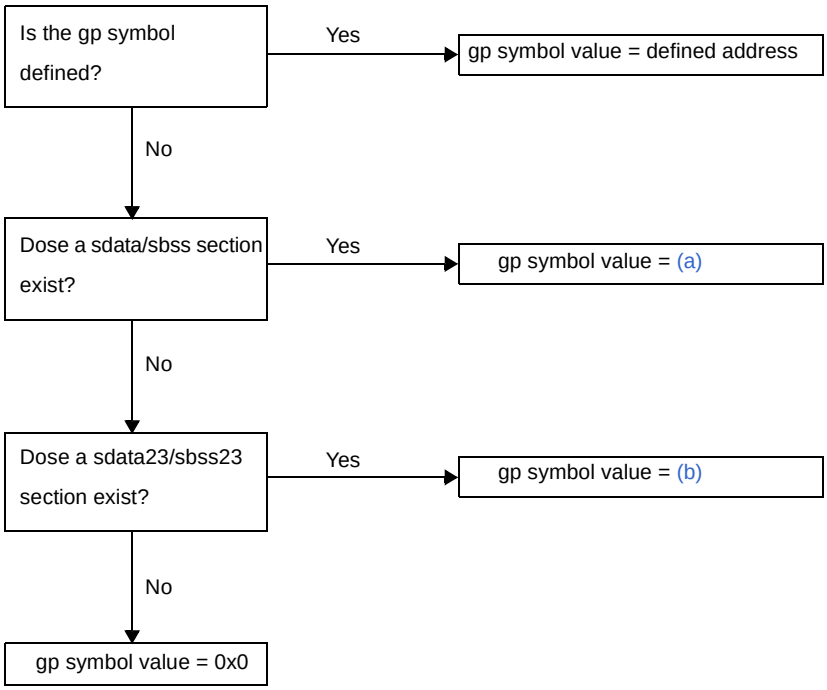
The following error message is output for code that makes references relative to the gp.

```
Undefined external symbol "GP-symbol (__gp_data)" referenced in "FILE"
```

(2) Rules for determining the gp symbol value

The value of the gp symbol is determined from sections with relocation attributes of sdata, sbss, sdata23, and sbss23, in the following order of precedence.

Figure 7-1. Rules for Determining the Global Pointer Value

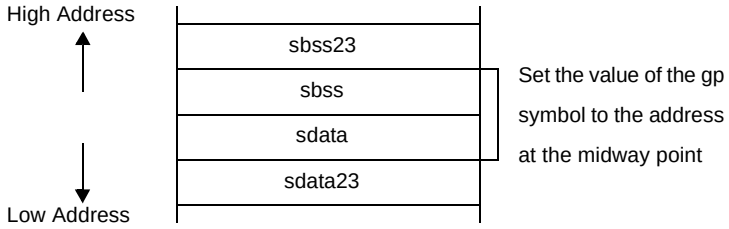


Below is an example of how the value of the gp symbol is determined.

(a) If there is a section with a relocation attribute of sdata or sbss

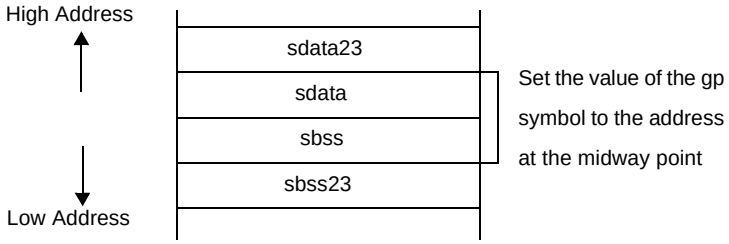
Sets the halfway point between the start address of the sdata or sbss section with the smallest address, and the end address of the sdata or sbss section with the greatest address (multiple of 2; if the midway point is an odd number, takes the first multiple of two) as the address value of the gp symbol.

<1> If an sdata and sbss section are located in this order, from smallest to highest address



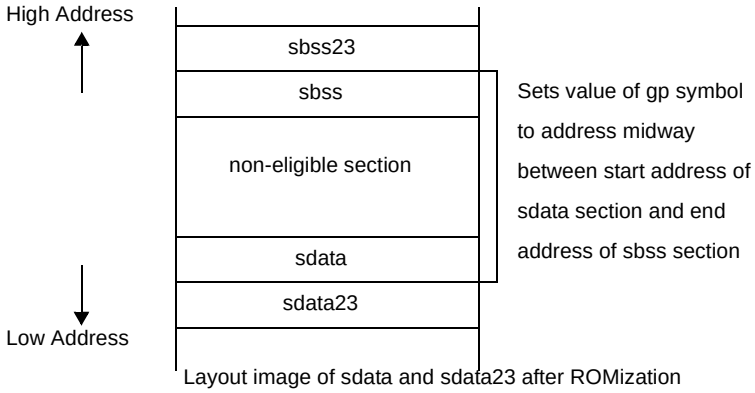
Layout image of sdata and sdata23 after ROMization

<2> If an sbss and sdata section are located in this order, from smallest to highest address



Layout image of sdata and sdata23 after ROMization

<3> If sdata and sbss sections are placed in this order, from lowest to highest address, and there is a non-eligible section in between the sdata and sbss sections

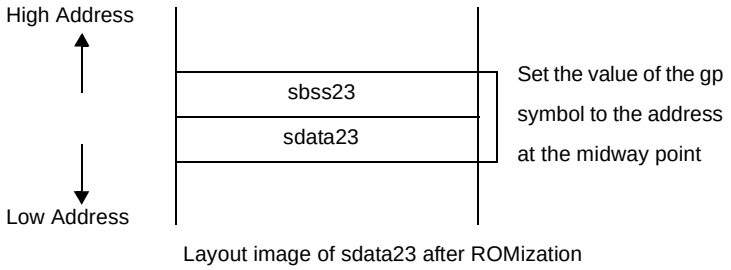


Layout image of sdata and sdata23 after ROMization

(b) If there is a section with a relocation attribute of sdata23 or sbss23

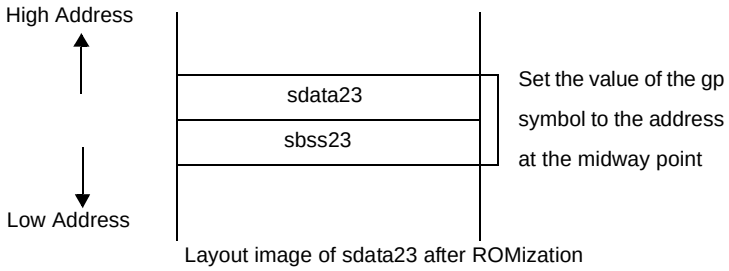
Sets the halfway point between the start address of the sdata23 or sbss23 section with the smallest address, and the end address of the sdata or sbss section with the greatest address (multiple of 2; if the midway point is an odd number, takes the first multiple of two) as the address value of the gp symbol.

<1> If an sdata23 and sbss23 section are located in this order, from smallest to highest address



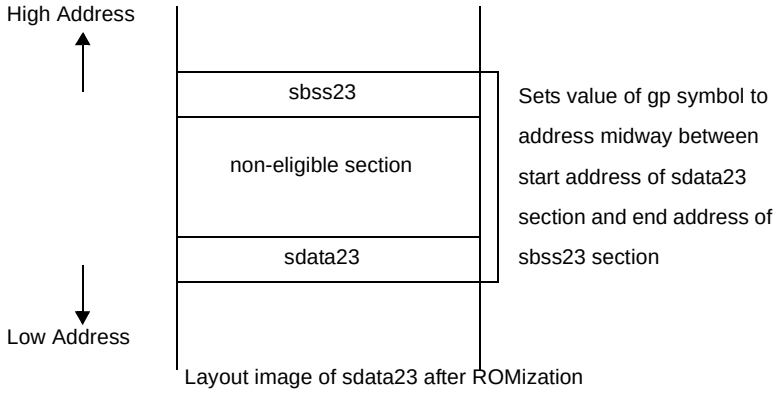
Layout image of sdata23 after ROMization

<2> If an sbss23 and sdata23 section are located in this order, from smallest to highest address



Layout image of sdata23 after ROMization

<3> If sdata23 and sbss23 sections are placed in this order, from lowest to highest address, and there is a non-eligible section in between the sdata23 and sbss23 sections



Layout image of sdata23 after ROMization

(c) If there are no sections with sdata, sbss, sdata23, or sbss23 relocation attributes

If there are no sdata, sbss, sdata23, or sbss23 sections, then the address value of the gp symbol is set to zero (0).

7.4.2 Element pointer (ep)

The element pointer is a pointer that is provided to realize faster access (loading and storing) by allocating data (variables) that are globally declared within an application to RAM area in RH850 device.

Data (variables) that is globally declared and allocated to internal RAM area is referenced with ep-relative.

(1) Setting the element pointer (ep)

Set the value of the element pointer symbol (ep symbol) as the address set in the global pointer (ep).

- The ep symbol is handled as the constant symbol name "__ep_data".
- Declare the ep symbol as a reference symbol (.extern) in the startup routine.
- rlink creates an externally defined symbol (.public) and determines the address of the ep symbol.

- The operations for defining and referencing the ep symbol are as follows.

(a) If there is only an ".extern" declaration of the ep symbol

rlink creates the definition information and sets the address automatically.

(b) If the ep symbol is defined

The defined address is used.

(c) If there is no ep symbol (it is not used)

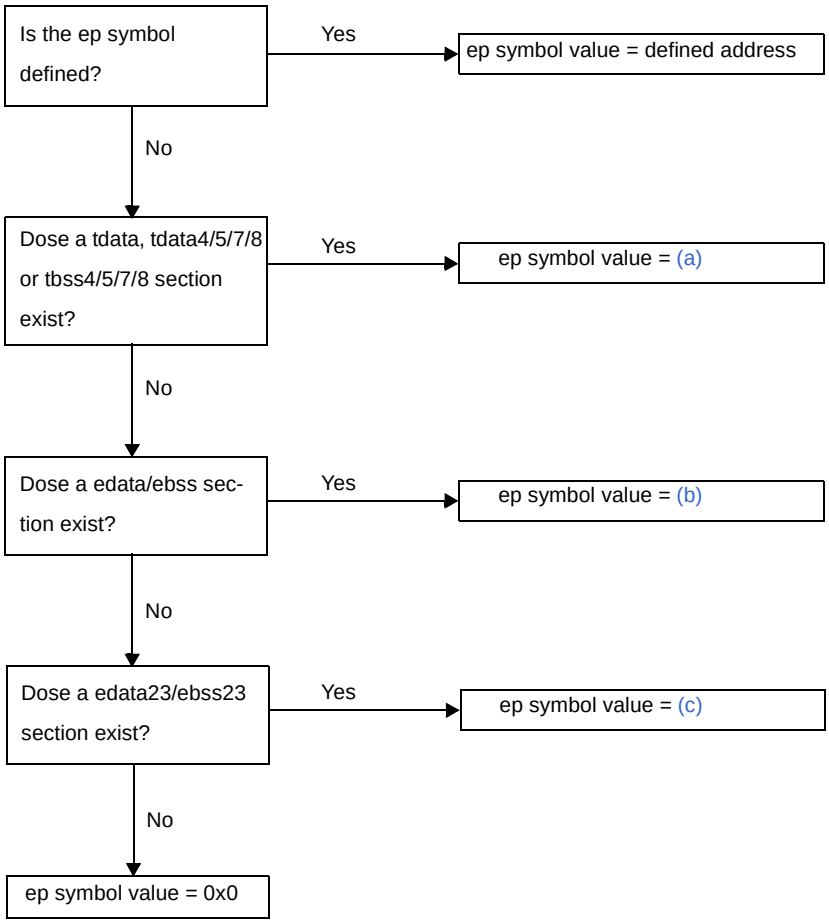
The following error message is output for code that makes references relative to the ep.

Undefined external symbol "EP-symbol (__ep_data)" referenced in "FILE"

(2) Rules for determining the ep symbol value

The value of the ep symbol is determined from sections with relocation attributes of tdata, tdata4/5/7/8, tbss4/5/7/8, edata, ebss, edata23 and ebss23, in the following order of precedence.

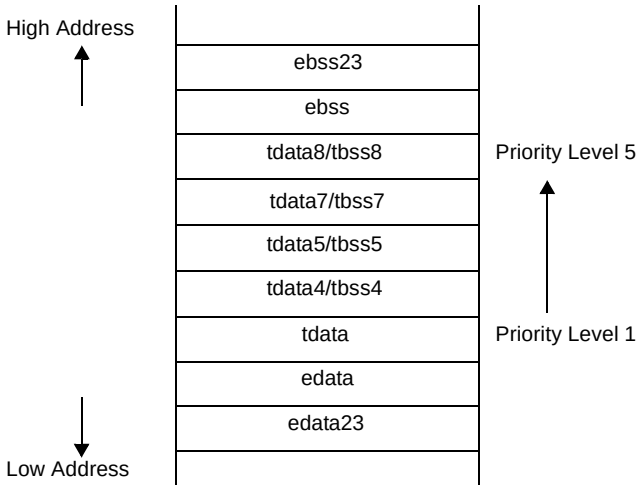
Figure 7-2. Rules for Determining the Element Pointer Value



Below is an example of how the value of the ep symbol is determined.

(a) If there are sections with relocation attributes of tdata, tdata4/5/7/8, and tbss4/5/7/8

The ep symbol is set to the start address of the first section in this order: tdata -> tdata4, or tbss4 -> ... -> tdata8, or tbss8.

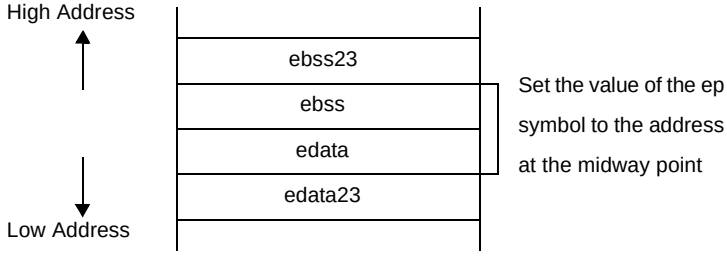


Layout image of tdata, tdata4/5/7/8, edata and edata32 after ROMization

(b) If there is a section with a relocation attribute of edata or ebss

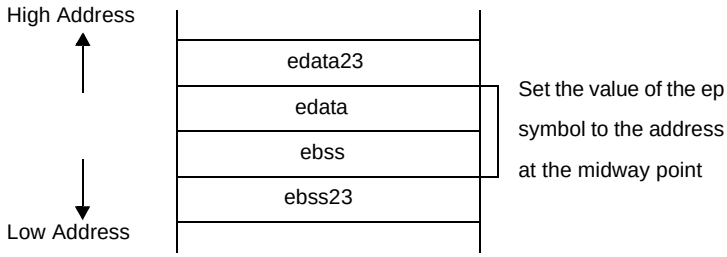
Sets the halfway point between the start address of the edata or ebss section with the smallest address, and the end address of the edata or ebss section with the greatest address (multiple of 2; if the midway point is an odd number, takes the first multiple of two) as the address value of the ep symbol.

<1> If an edata and ebss section are located in this order, from smallest to highest address



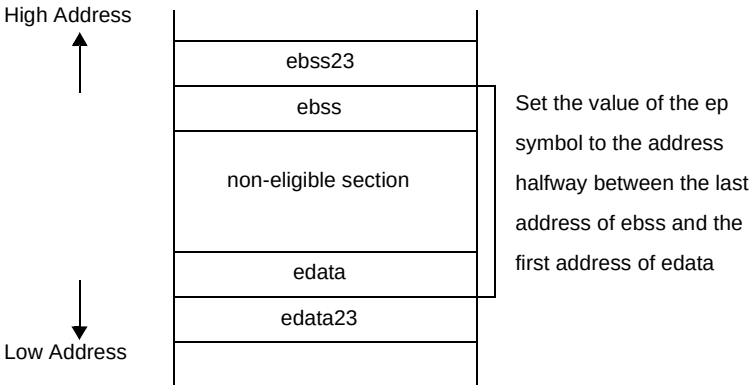
Layout image of edata and edata23 after ROMization

<2> If an ebss and edata section are located in this order, from smallest to highest address



Layout image of edata and edata23 after ROMization

<3> If edata and ebss sections are placed in this order, from lowest to highest address, and there is a non-eligible section in between the edata and ebss sections



Layout image of edata and edata23 after ROMization

(c) If there is a section with a relocation attribute of edata23 or ebss23

Sets the halfway point between the start address of the edata23 or ebss23 section with the smallest address, and the end address of the edata23 or ebss23 section with the greatest address (multiple of 2; if the midway point is an odd number, takes the first multiple of two) as the address value of the ep symbol.

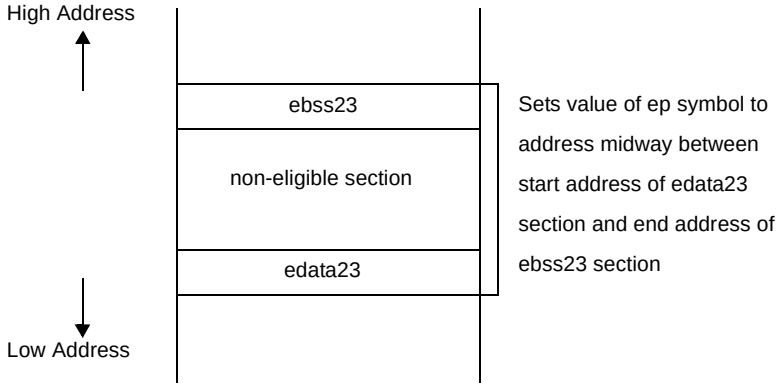
<1> If an edata23 and ebss23 section are located in this order, from smallest to highest address

Layout image of edata after ROMization

<2> If an ebss23 and edata23 section are located in this order, from smallest to highest address

Layout image of edata23 after ROMization

<3> If edata23 and ebss23 sections are placed in this order, from lowest to highest address, and there is a non-eligible section in between the edata23 and ebss23 sections



Layout image of edata23 after ROMization

(d) If there are no sections with tdata, tdata4/5/7/8, tbss4/5/7/8, edata, ebss, edata23, or ebss23 relocation attributes

If there are no data, tdata4/5/7/8, tbss4/5/7/8, edata, ebss, edata23, or ebss23 sections, then the address value of the ep symbol is set to zero (0).

7.5 ROMization

This section describes an outline of the ROMization procedure, operation method, etc.

7.5.1 Outline

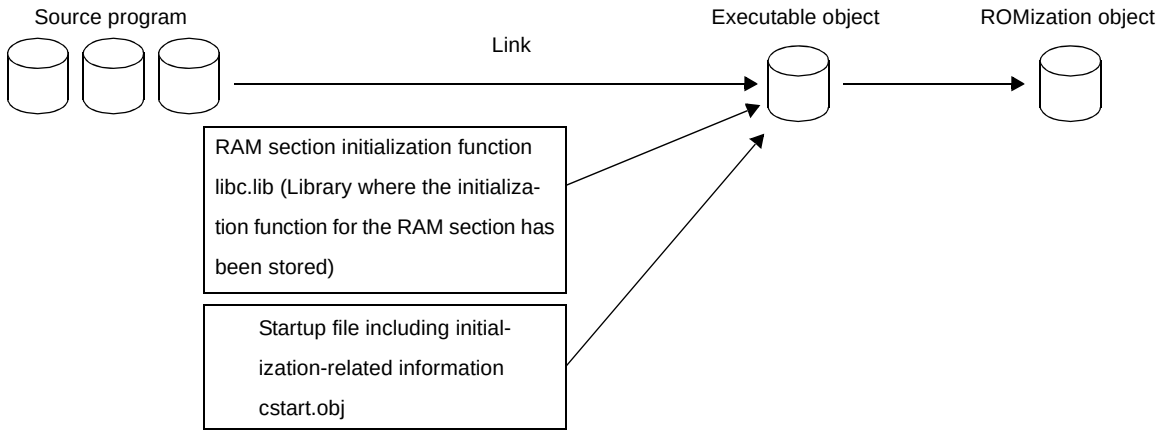
When a variable is declared globally or static within a program, the variable is allocated to the data-attribute section in RAM if the variable has a initial value, or to the bss-attribute section if it does not have a initial value. When the variable has a initial value, that initial value is also stored in RAM. In addition, program code may be stored in the internal RAM area to speed up applications.

In the case of an embedded system, if a debug tool such as an in-circuit emulator is used, executable modules can be downloaded and executed just as they are in the allocation image. However, if the program is actually written to the target system's ROM area before being executed, the initial value information that has been allocated to the data-attribute section and the program code that has been allocated to a RAM area must be deployed in RAM prior to execution. In other words, data that is residing in RAM must be deployed in ROM, and this means that data must be copied from ROM to RAM before the corresponding application is executed.

"ROMization" refers to the packing of the initial values of variables in data-attribute sections and program code to be allocated to the RAM into a single section of ROM. Allocating this section to the ROM and calling the copy function provided by the CC-RH make it easy to deploy the initial values and program code to the RAM.

The following figure shows an outline of the operation flow in creating objects for ROMization.

Figure 7-3. Creation of Object for ROMization



When ROMization objects are created as shown in the "Figure 7-3. Creation of Object for ROMization", execution of the _INITSCT_RH copies the data to be allocated to RAM from the packed ROM section.

The function used to copy from the ROM area to the RAM area is as follows.

- _INITSCT_RH

This function is stored in the library "libc.lib".

If the object files resolved for relocation include symbol information and debug information, the CC-RH creates a ROMization object module file without deleting them. Therefore, the debugger can debug the source even with a ROMization object module file.

7.5.2 Creating ROMized load module file

This section explains how to create the ROMized load module.

The -rom option is used for ROMization. The code is as follows.

```
-rom=name of the initial-value section=name of the destination section[,name of the initial-
value section=name of the destination section]...
```

The -start option must also be used to specify the addresses of the initial-value section and destination section.

```
-start=[(]section-name[{:|,}section-name]...[)][{:|,}section-name]...[/destination-
address][,[(]section-name[{:|,}section-name]...[)][{:|,}section-name]...[/destination-
address]]...
```

Assume that the program contains seven sections: .text, .data, .zdata, .zbss, .bss, .sdata, and .sbss. If .text, r0 relative sections, and r4 relative sections are to be allocated to addresses 0x0, 0xFE000000, and 0xFE001000 respectively before execution of the user program, the code will be as follows.

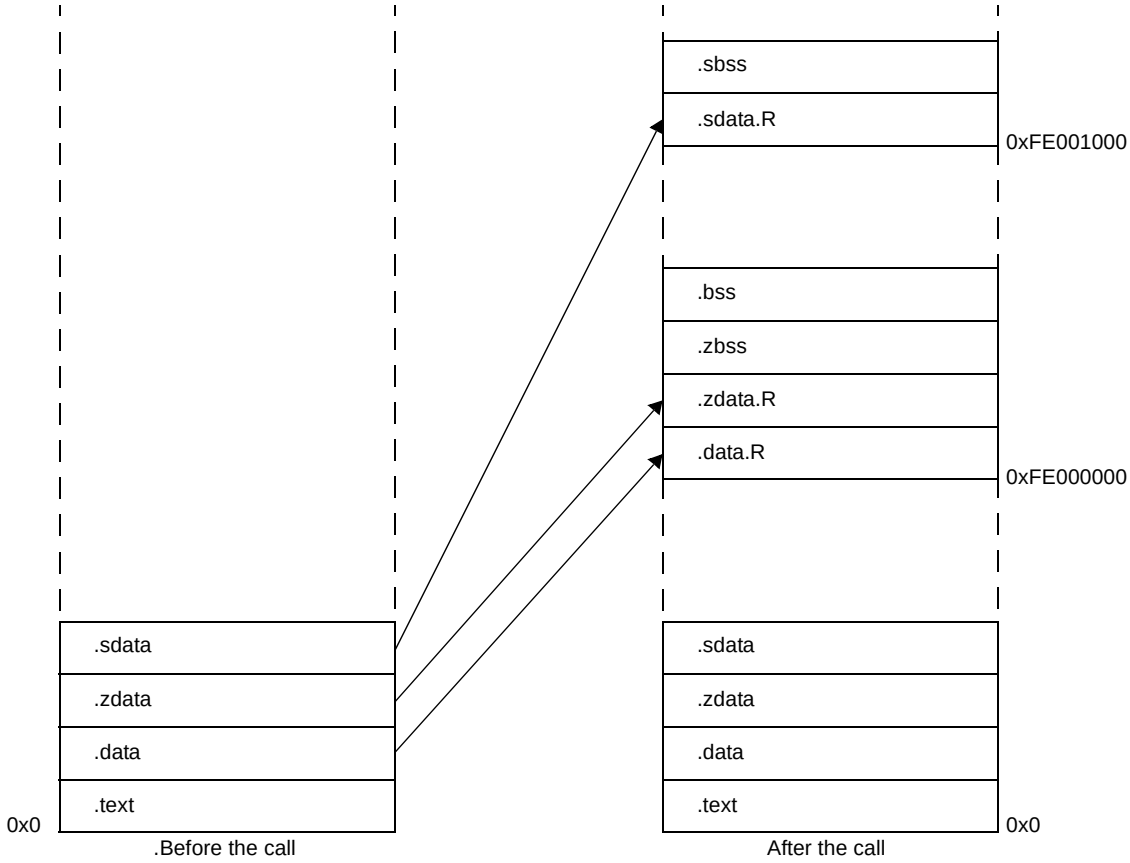
```
-start=.text,.data,.zdata,.sdata/0
-start=.data.R,.zdata.R,.zbss,.bss/fe000000
-start=.sdata.R,.sbss/fe001000
-rom=.data=.data.R,.zdata=.zdata.R,.sdata=.sdata.R
```

.data and .zdata are allocated to the range following the .text section at address 0x0.

When the user program is executed, .data.R, .zdata.R, .zbss, and .bss at address 0xFE000000 and .sdata.R and .bss at address 0xFE001000 are initialized before they are used.

An image of this operation is shown below.

Figure 7-4. Image of Processing Before and After Copy Function Call



CHAPTER 8 REFERENCING COMPILER AND ASSEMBLER

This chapter explains how to handle arguments when a program is called by the CC-RH.

8.1 Function Call Interface

This section describes how to handle arguments when a program is called by the CC-RH.

8.1.1 General-purpose registers guaranteed before and after function calls

Some general-purpose registers are guaranteed to be the same before and after a function call, and others are not. The rules for guaranteeing general-purpose registers are as follows.

(1) Registers guaranteed to be same before and after function call (Callee-Save registers)

These general-purpose registers must be saved and restored by the called function. It is thus guaranteed to the caller that the register contents will be the same before and after the function call.

r20, r21, r22, r23, r24, r25, r26, r27, r28, r29, r30[Note], r31

Note r30 (EP) may be locked throughout the entire program. If it is locked, then the contents of the general-purpose registers are never changed anywhere in the program, and consequently it is not necessary for the callee to save and restore the registers.

(2) Registers not guaranteed to be same before and after function call (Caller-Save registers)

General-purpose registers other than the Callee-Save registers above could be overwritten by the called function. It is thus not guaranteed to the caller that the register contents will be the same before and after the function call.

Remarks 1. The user must take responsibility for overwriting register r1, because it may be used by the assembler.

2. r2 may be reserved by the OS. The rules described here do not apply to reserved registers, because the compiler does not use them as general-purpose registers. The user is responsible for overwriting them.

3. r3 is a stack pointer. The rules described here do not apply to it, because it is not used as a general-purpose register. The user is responsible for overwriting it.

4. r4 (GP) and r5 (TP) may be locked throughout the entire program. If so, then the rules described here do not apply to them, because the contents of the general-purpose registers are never changed anywhere in the program. The user is responsible for overwriting them.

5. It is possible to specify usage of r2 and r30 using options.

8.1.2 Setting and referencing arguments and return values

(1) Passing arguments

Arguments can be passed via registers or the stack. The manner in which each argument is passed is determined by the procedure below.

(a) A memory image to which each argument is assigned is created on the stack

<1> Scalar values that are 2 bytes or smaller are promoted to 4-byte integers before being stored.

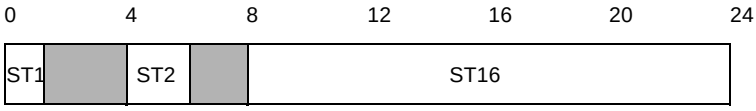
<2> Each argument is essentially aligned on a 4-byte boundary.

<3> If a return value is a structure or union, then the start of the memory image is set to the address at which to write the return-value data.

<4> If the function prototype is unknown, then each scalar-type argument is stored as follows.

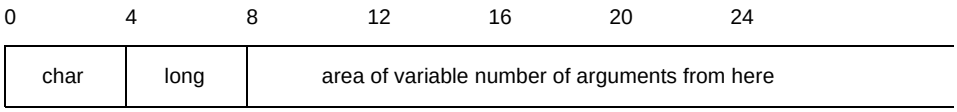
- 1-byte scalar integer ->Promoted to 4-byte integer, then stored
- 2-byte scalar integer ->Promoted to 4-byte integer, then stored
- 4-byte scalar integer ->Stored as-is
- 8-byte scalar integer ->Stored as-is
- 4-byte scalar floating-point number ->Promoted to 8-byte floating-point number, then stored
- 8-byte scalar floating-point number ->Stored as-is

Examples 1. Function prototype : f(ST1, ST2, ST16)
Example where STx represents a structure with a size of x[byte]



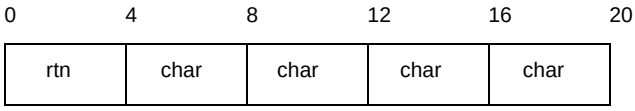
In the case of a structure or union whose size is not a multiple of 4, it is possible to add padding between the parameters. The contents of the padded area are undefined.

2. Function prototype : f(char, long, ...)
Example of accepting variable number of actual arguments



The "area of variable number of arguments from here" consumes memory for the number of actual arguments that are set.

3. Function prototype : ST4 f(char, char, char, char)



An address of the location to which to write the ST4 return value is passed through rtn.

(b) The first 4 words (16 bytes) of the created memory image are passed via registers r6 to r9, and the portion that does not fit is passed on the stack

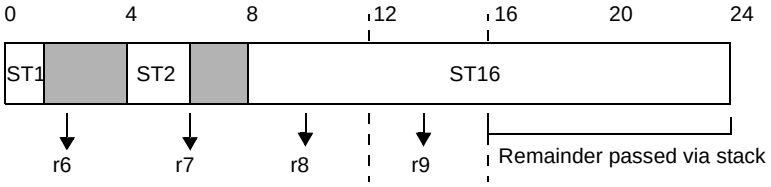
<1> If the arguments passed via the registers, it's loaded by the word units to each register (r6-r9). The byte units and the half-word units aren't loaded.

<2> The arguments passed on the stack are set in the stack frame of the calling function.

<3> Arguments passed on the stack are stored on the stack in order from right to left in the memory image. Thus the word data at the 16-byte offset location of the memory image is placed in the location closest to 0.

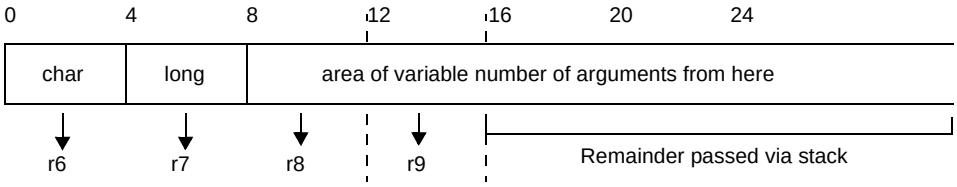
Remark See "8.1.4 Stack frame" about how data is placed on the stack.

Examples 1. Function prototype : f(ST1, ST2, ST16)
Example where STx represents a structure with a size of x[byte]



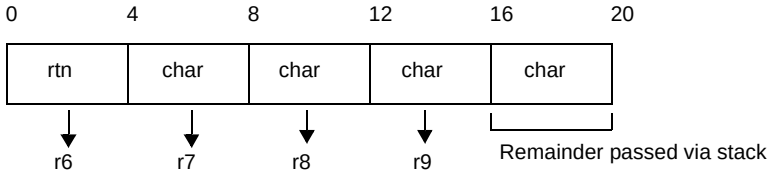
Even if only part of a structure (in this case, ST16) can fit in the registers, that part is still passed via the registers.

2. Function prototype : f(char, long, ...)
Example of accepting variable number of actual arguments



Even if the number of arguments is variable, the arguments are passed via registers where this is possible.

3. Function prototype : ST4 f(char, char, char, char)



Even if only passing four arguments of type char, the fourth argument may be passed on the stack, depending on the return value.

(2) How return values are passed

There are three ways to pass return values, as follows.

(a) If value is scalar type 4 bytes or smaller

The return value is returned to the caller via r10.
If the value is a scalar type less than 4 bytes in size, data promoted to 4 bytes is set in r10.
Zero promotion is performed on unsigned return values, and signed promotion on signed return values.

(b) If value is scalar type 8 bytes

The return value is returned to the caller via r10 and r11.
The lower 32 bits are set in r10, and the upper 32 bits in r11.

(c) If the value is a structure or union

If the return value is a structure or union, then when the caller calls the function, it sets the address to which to write the return value in the argument register r6. The caller sets the return value in the address location indicated by parameter register r6, and returns to the calling function.
Upon return, r6 and r10 are undefined (same as Caller-Save registers) to the calling function.
All structures and unions are turned by the same method, regardless of size. The actual data of the structure or union is not returned in the register.

8.1.3 Address indicating stack pointer

An address that is a multiple of 4 is set in the stack pointer.

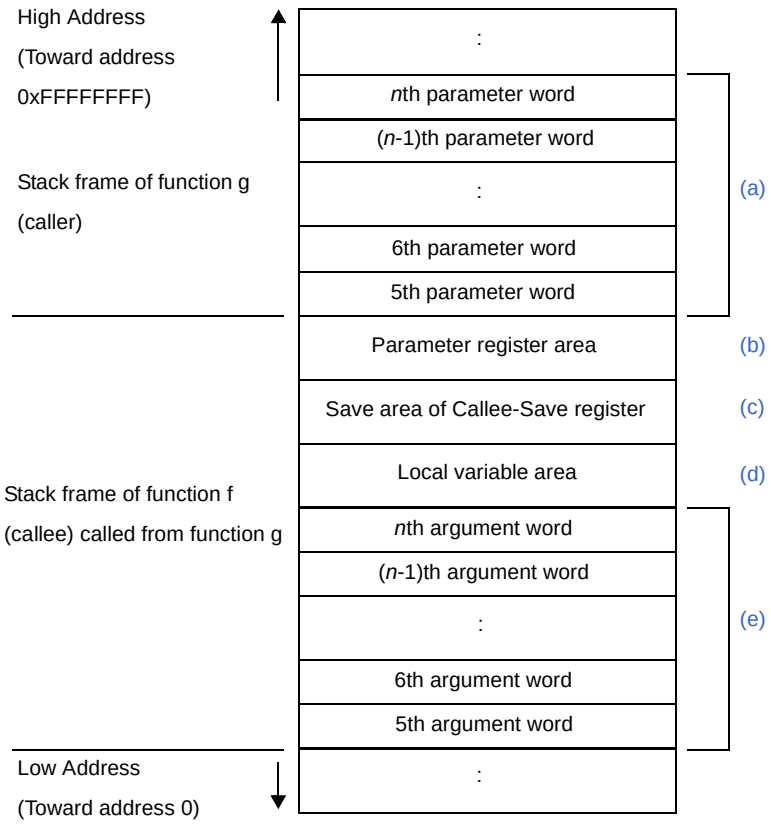
Although the addresses indicated by the stack pointer must all be either multiples of 4, it is not necessary for all the data stored on the stack to be aligned on either a 4-byte boundary. Each data item is stored on the stack at the location in accordance with its alignment. For example, if data is of type char, it can be stored on a 1-byte boundary even on the stack, because its data alignment is 1.

8.1.4 Stack frame

(1) Structure of the stack frame

Below is shown the stack frame of functions f and g from the perspective of function f, when function f is called by function g.

Figure 8-1. Contents of Stack Frame



Below is the range of the area that function f can reference and set.

(a) Parameter words 5 to *n*

This is the area where parameters beyond 4 words (16 bytes) are stored, when function f has parameters larger than 4 words in size. The size of this area is 0 when the parameter size is 4 words or less.

(b) Parameter register area

This area is for storing parameters passed in the registers (r6 to r9). The size is not locked at 16 bytes; the size is 0 if not needed.

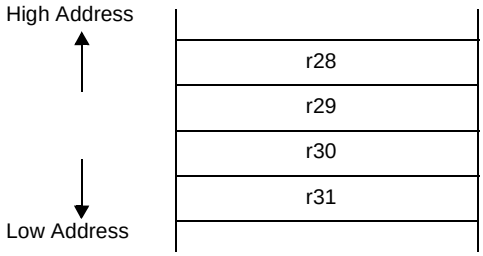
For details about the parameter register area, see "(2) Parameter register area".

(c) Save area of Callee-Save register

This area is for saving the Callee-Save registers used in function f. If it is necessary to save registers, then this area must be large enough for the number of registers.

Registers are essentially saved and restored using prepare/dispose instructions, so registered are stored in this save area in order of ascending register number.

For example, r28 to r31 would be saved in the following order.



(d) Local variable area

This stack area is used for local variables.

(e) 5th to *n*th argument words

Parameters beyond 4 words in size are stored in this area when function f is called by another function. The area for arguments needed when calling another function is allocated on function f's stack frame, and set there.

If fewer than 4 words are needed for the call's arguments, then the size of this area is 0.

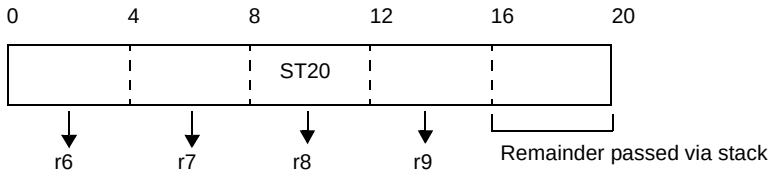
(2) Parameter register area

If the size of the parameters is greater than 4 words (16 bytes), then the required area for the size of the parameter register area is allocated. The size of this area will be either 0, 4, 8, 12, or 16 bytes, because it stores parameter registers r6 to r9, as necessary.

This area is for storing parameter registers when it is necessary to reference the contiguous placement relationship between the parameter register contents and parameters on the stack.

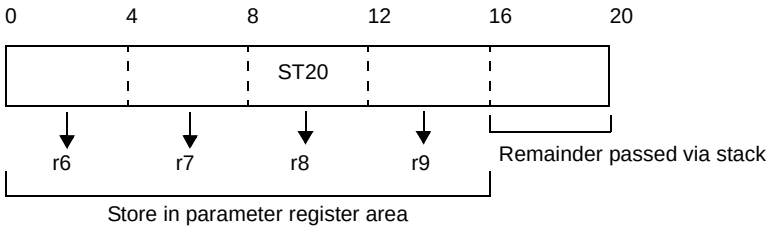
For example, when passing the value of a 20-byte structure argument, 16 bytes are passed in r6 to r9, and the remaining 4 bytes (the 5th parameter word) are passed on the stack.

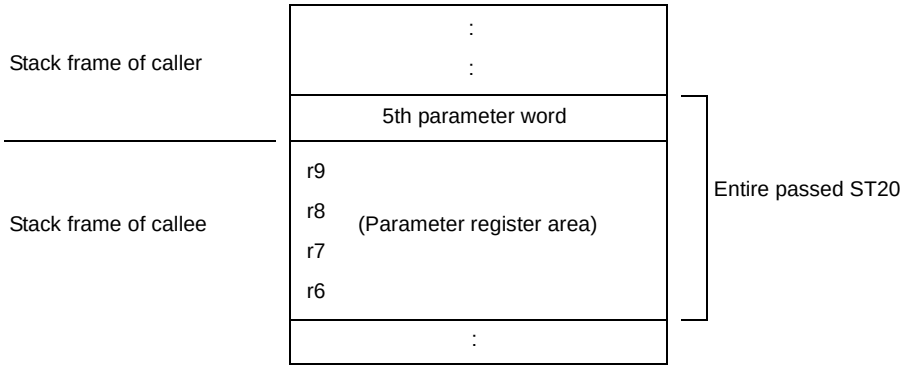
Examples 1. Function prototype : f(ST20)



When referencing the value of the passed structure as a whole, it is necessary to align the entire structure contiguously in memory, but the structure is split unto the register portion and memory portion immediately after the function call.

In this case, the called function can reference the passed ST20 structure in memory be storing the parameter register on the stack.



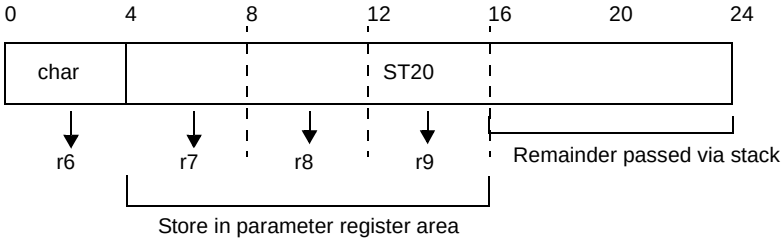


Below is a concrete case of parameters where this area is needed.

If none of these apply, then the parameter register area is not needed (size 0) because it is not necessary to store the parameter registers in the parameter register area.

(a) When a structure or union spans the parameter registers and stack

Example Function prototype : f(char, ST20)



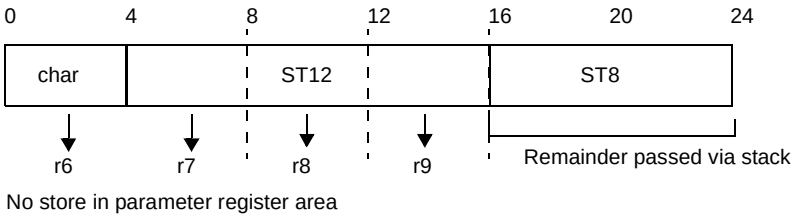
In this case, r7 to r9 are stored in the parameter register area.

r6 is not stored because it is not needed to align ST20 contiguously in memory.

Therefore the size of the parameter register area is 12 bytes.

If a structure or union does not span the parameter register and stack, then it is not necessary to store it in the parameter register area, and the size of the parameter register area is therefore 0.

Example Function prototype : f(char, ST12, ST8)

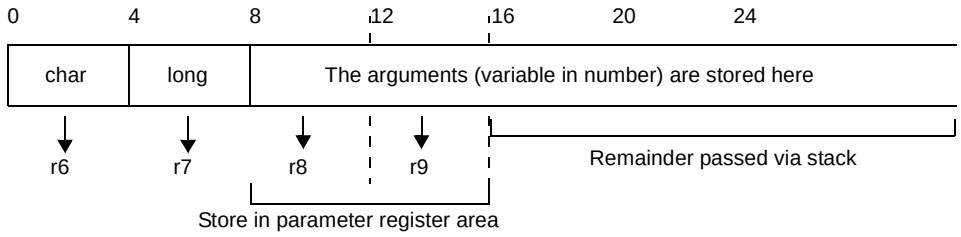


In this case, all of ST12 fits in the parameter registers, ST8 is not passed in the parameter registers. Since no arguments span the parameter registers and stack, the size of the parameter register area is 0 bytes.
If a structure or union is passed in its entirety via the parameter registers, the local variable area is used to expand it in memory.

(b) Accepting variable number of actual arguments

To receive a variable number of arguments, the arguments (including the last parameter) need to be stored in the parameter register area.

Example Function prototype : f(char, long, ...)



In this case, the parameter registers corresponding to the variable number of actual arguments (r8 and r9) are stored in the parameter register area.
Therefore the size of the parameter register area is 8 bytes.

8.2 Calling of Assembly Language Routine from C Language

This section explains the points to be noted when calling an assembler function from a C function.

(1) Identifier

If external names, such as functions and external variables, are described in the C source by the CC-RH, they are prefixed with "_" (underscore) when they are output to the assembler.

Table 8-1. Identifier

C	Assembler
func1 ( )	_func1

Prefix "_" to the identifier when defining functions and external variables with the assembler and remove "_" when referencing them from a C function.

(2) Stack frame

The CC-RH generates codes on the assumption that the stack pointer (SP) always indicates the lowest address of the stack frame. Therefore, the address area lower than the address indicated by SP can be freely used in the assembler function after branching from a C source to an assembler function. Conversely, if the contents of the higher address area are changed, the area used by a C function may be lost and the subsequent operation cannot be guaranteed. To avoid this, change SP at the beginning of the assembler function before using the stack.
At this time, however, make sure that the value of SP is retained before and after calling.
When using a register variable register in an assembler function, make sure that the register value is retained before and after the assembler function is called. In other words, save the value of the register variable register before calling the assembler function, and restore the value after calling.
The register for register variable that can be used differ depending on the register mode.

Table 8-2. Registers for Register Variables

Register Modes	Register for Register Variable
22-register mode	r25, r26, r27, r28, r29
32-register mode	r20, r21, r22, r23, r24, r25, r26, r27, r28, r29

(3) Return address passed to C function

The CC-RH generates codes on the assumption that the return address of a function is stored in link pointer lp (r31). When execution branches to an assembler function, the return address of the function is stored in lp. Execute the jmp [lp] instruction to return to a C function.

8.3 Calling of C Language Routine from Assembly Language

This section explains the points to be noted when calling a C function from an assembler function.

(1) Stack frame

The CC-RH generates codes on the assumption that the stack pointer (SP) always indicates the lowest address of the stack frame. Therefore, set SP so that it indicates the higher address of an unused area of the stack area before branching from an assembler function to a C function. This is because the stack frame is allocated towards the lower addresses.

(2) Work register

The CC-RH retains the values of the register for register variable before and after a C function is called but does not retain the values of the work registers. Therefore, do not leave a value that must be retained assigned to a work register.
The register for register variable and work registers that can be used differ depending on the register mode.

Table 8-3. Registers for Register Variables

Register Modes	Register for Register Variable
22-register mode	r25, r26, r27, r28, r29
32-register mode	r20, r21, r22, r23, r24, r25, r26, r27, r28, r29

Table 8-4. Work Register

Register Modes	Work Register
22-register mode	r10, r11, r12, r13, r14
32-register mode	r10, r11, r12, r13, r14, r15, r16, r17, r18, r19

(3) Return address returned to assembler function

The CC-RH generates codes on the assumption that the return address of a function is stored in link pointer lp (r31). When execution branches to a C function, the return address of the function must be stored in lp. Execution is generally branched to a C function using the jarl instruction.

8.4 Reference of Argument Defined by Other Language

The method of referring to the variable defined by the assembly language on the C language is shown below.

Example Programming of C Language

```
extern  char    c;
extern  int     i;

void subf() {
        c = 'A';
        i = 4;
}
```

The CC-RH assembler performs as follows.

```
        .public _i
        .public _c
        .dseg   SDATA
_i:
        .db4    0x0
_c:
        .db     0x0
```

8.5 General-purpose Registers

How the CC-RH uses the general-purpose registers are as follows.

Table 8-5. Using General-purpose Registers

Register	Usage
r0	Used for operation as value of 0. Base register of .data/.bss section reference
r1	caller save register
r2	caller save register Reserved for system (OS) (Switched via option)
r3 (sp)	Stack pointer

Register	Usage
r4 (gp)	Global pointer for PID Fixed
r5 (tp)	Global pointer for constant data caller save register
r6 to r19	caller save register
r20 to r29	callee save register
r30 (ep)	Element pointer Fixed or callee save register (Switched via option)
r31 (lp)	Link pointer callee save register

CHAPTER 9 CAUTIONS

This chapter explains the points to be noted when using the CC-RH.

9.1 Volatile Qualifier

When a variable is declared with the volatile qualifier, the variable is not optimized and optimization for assigning the variable to a register is no longer performed. When a variable with volatile specified is manipulated, a code that always reads the value of the variable from memory and writes the value to memory after the variable is manipulated is output. The access width of the variable with volatile specified is not changed.

A variable for which volatile is not specified is assigned to a register as a result of optimization and the code that loads the variable from the memory may be deleted. When the same value is assigned to variables for which volatile is not specified, the instruction may be deleted as a result of optimization because it is interpreted as a redundant instruction. The volatile qualifier must be specified especially for variables that access a peripheral I/O register, variables whose value is changed by interrupt servicing, or variables whose value is changed by an external source.

The following problem may occur if volatile is not specified where it should.

- The correct calculation result cannot be obtained.
- Execution cannot exit from a loop if the variable is used in a for loop.
- The order in which instructions are executed differs from the intended order.
- The number times memory is accessed and the width of access are not as intended.

If it is clear that the value of a variable with volatile specified is not changed from outside in a specific section, the code can be optimized by assigning the unchanged value to a variable for which volatile not specified and referencing it, which may increase the execution speed.

Example Source and output code if volatile is not specified

If volatile is not specified for "variable a", "variable b", and "variable c", these variables are assigned to registers and optimized. For example, even if an interrupt occurs in the meantime and the variable value is changed by the interrupt, the changed value is not reflected.

```
int a;
int b;
void func(void){
    if(a <= 0){
        b++;
    } else {
        b+=2;
    }
    b++;
}
```

```
_func:
        MOVHI   HIGHW1(#_a), R0, R6
        LD.W    LOWW(#_a)[R6], R6
        CMP     0x00000000, R6
        MOVHI   HIGHW1(#_b), R0, R6
        LD.W    LOWW(#_b)[R6], R6
        BGT     .BB1_2          ; bb3
.BB1_1:     ; bb1
        ADD     0x00000001, R6
        BR      .BB1_3          ; bb9
.BB1_2:     ; bb3
        ADD     0x00000002, R6
.BB1_3:     ; bb9
        ADD     0x00000001, R6
        MOVHI   HIGHW1(#_b), R0, R7
        ST.W    R6, LOWW(#_b)[R7]
        JMP     [R31]
```

Example Source and output code if volatile is specified

If volatile is specified for "variable a", "variable b", and "variable c", a code that always reads the values of these variables from memory and writes them to memory after the variables are manipulated is output. For example, even if, an interrupt occurs in the meantime and the values of the variables are changed by the interrupt, the result in which the change is reflected can be obtained. (In this case, interrupts may have to be disabled while the variables are manipulated, depending on the timing of the interrupt.)

When volatile is specified, the code size increases compared with when volatile is not specified because the memory has to be read and written.

```
volatile int a;
volatile int b;
void func(void){
    if(a <= 0){
        b++;
    } else {
        b+=2;
    }
    b++;
}
```

```
_func:
        MOVHI   HIGHW1(#_a), R0, R6
        LD.W    LOWW(#_a)[R6], R6
        CMP     0x00000000, R6
        BGT     .BB1_2          ; bb3
.BB1_1:    ; bb1
        MOVHI   HIGHW1(#_b), R0, R6
        LD.W    LOWW(#_b)[R6], R6
        ADD     0x00000001, R6
        BR      .BB1_3          ; bb9
.BB1_2:    ; bb3
        MOVHI   HIGHW1(#_b), R0, R6
        LD.W    LOWW(#_b)[R6], R6
        ADD     0x00000002, R6
.BB1_3:    ; bb9
        MOVHI   HIGHW1(#_b), R0, R7
        ST.W    R6, LOWW(#_b)[R7]
        LD.W    LOWW(#_b)[R7], R6
        ADD     0x00000001, R6
        ST.W    R6, LOWW(#_b)[R7]
        JMP     [R31]
```

9.2 V850E3v5 G3K Core Specification for Assembler (-Xcpu=g3k Option)

The following instruction sets cannot be specified.

- Hardware multithreading feature instructions
- Virtualization support feature instructions
- MMU control instructions
- SIMD instructions
- Floating-point operation instructions

The above instruction sets cause assemble errors when the V850E3v5 G3K core is specified. If any of them is specified, the assembler outputs the following message.

```
E0550269 : Illegal mnemonic(cannot use this mnemonic ins RH850 "G3K" core).
```

APPENDIX A WINDOW REFERENCE

This section describes the window, panel, and dialog boxes related to coding.

A.1 Description

Below is a list of the window, panel, and dialog boxes related to coding.

Table A-1. List of Window/Panel/Dialog Boxes

Window/Panel/Dialog Box Name	Function Description
Editor panel	This panel is used to display and edit files.
Encoding dialog box	This dialog box is used to select a file-encoding.
Bookmarks dialog box	This dialog box is used to display and delete bookmarks.
Go to Line dialog box	This dialog box is used to move the caret to a specified source line.
Jump to Function dialog box	This dialog box is used to select a function to be jumped if there are some functions with the same names when a program jumps to the function specified on the Editor panel.
Print Preview window	This window is used to preview the source file before printing.
Open File dialog box	This dialog box is used to open a file.

Editor panel

This panel is used to display and edit files.

When opened the file encoding and newline code is automatically detected and retained when it is saved. You can open a file with a specific encoding selected in the Encoding dialog box. If the encoding and newline code is specified in the Save Settings dialog box then the file is saved with those settings.

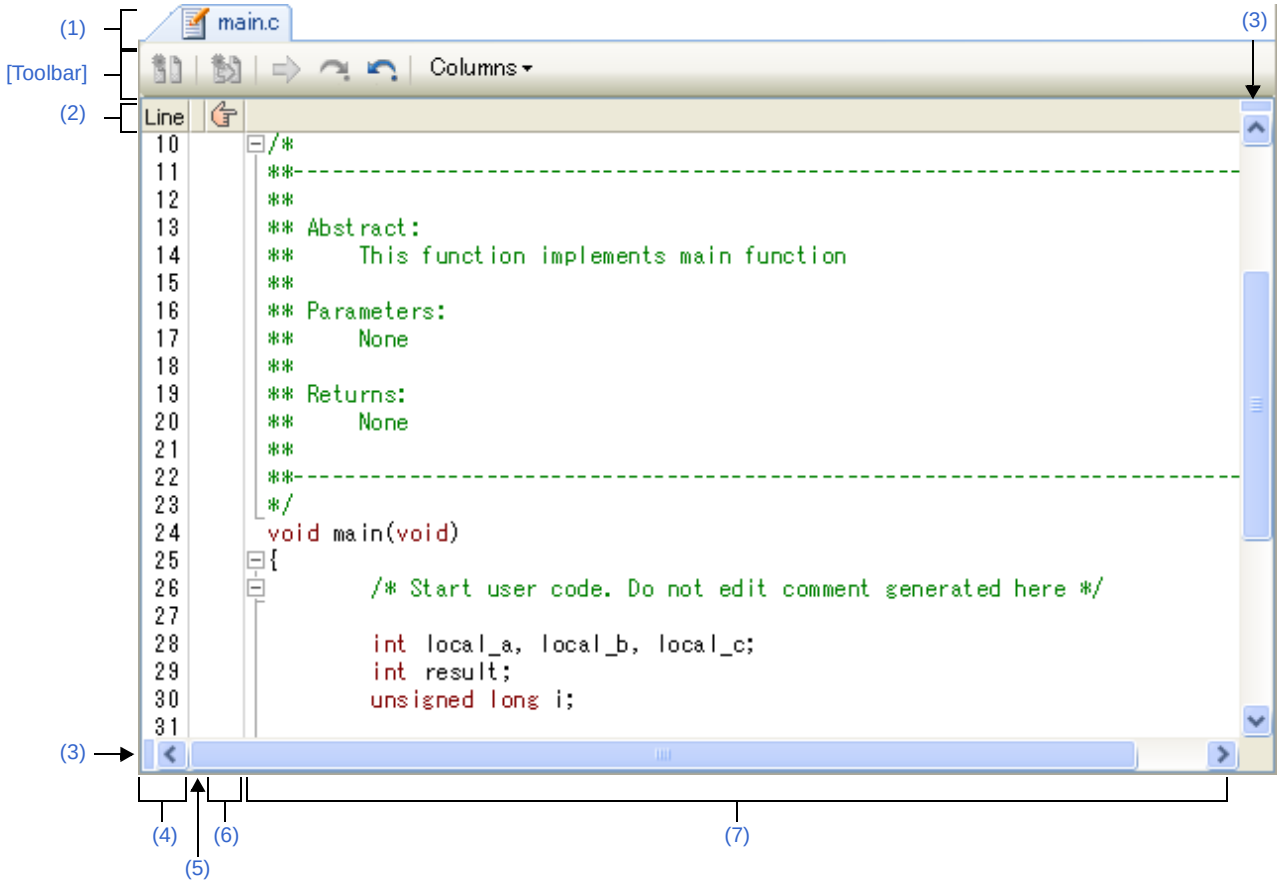
This panel can be opened multiple times (max. 100 panels).

Cautions 1. When a project is closed, all of the Editor panels displaying a file being registered in the project are closed.

2. When a file is excluded from a project, the Editor panel displaying the file is closed.

Remark This panel can be zoomed in and out by 100% in the tool bar, or by moving the mouse wheel forward or backward while holding down the [Ctrl] key.

Figure A-1. Editor Panel



The following items are explained here.

- [How to open]
- [Description of each area]
- [Toolbar]
- [[File] menu (Editor panel-dedicated items)]
- [[Edit] menu (Editor panel-dedicated items)]
- [[Window] menu (Editor panel-dedicated items)]
- [Context menu]

[How to open]

- On the Project Tree panel, double click a file.
- On the Project Tree panel, select a source file, and then select [Open] from the context menu.
- On the Project Tree panel, select a source file, and then select [Open with Internal Editor...] from the context menu.
- On the Project Tree panel, select [Add] >> [Add New File...] from the context menu, and then create a text file or source file.

[Description of each area]

(1) Title bar

The name of the open text file or source file is displayed.
Marks displayed at the end of the file name indicate the following:

Mark	Description
*	The text file has been modified since being opened.
(Read only)	The opened text file is read only.

(2) Column header

The title of each column on the Editor panel is displayed (hovering the mouse cursor over this area displays the title name).

Display	Title Name	Description
Line	Line	Displays line numbers (see "(4) Line number area").
(No display)	Selection	The display is colored to reflect the state in terms of saving of the state of editing (see "(5) Selection area").
	Main	Dislays bookmarks (see "(6) Main area").

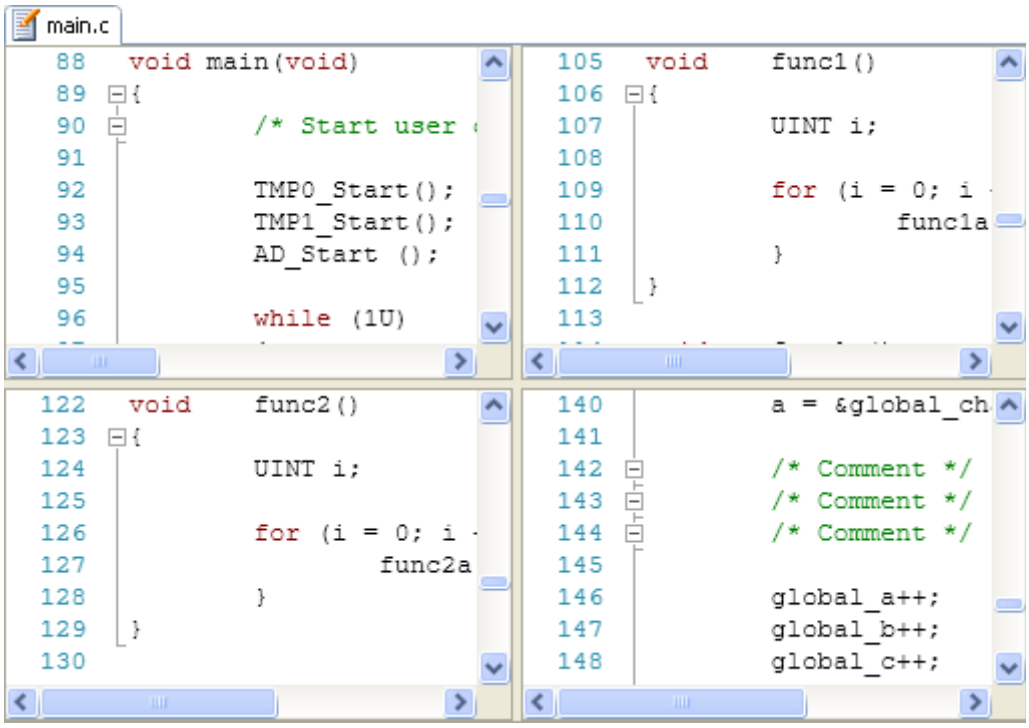
Remark Show/hide of the column header can be switched by the setting of the toolbar.

(3) Splitter bars

You can split the Editor panel by using the horizontal and vertical splitter bars within the view. This panel can be split up to two times vertically, and two times horizontally.

- To split this panel, drag the splitter bar down or to the right to the desired position, or double-click any part of the splitter bar.
- To remove the split, double-click any part of the splitter bar.

Figure A-2. Editor Panel (Vertical/Horizontal Two-way Split View)

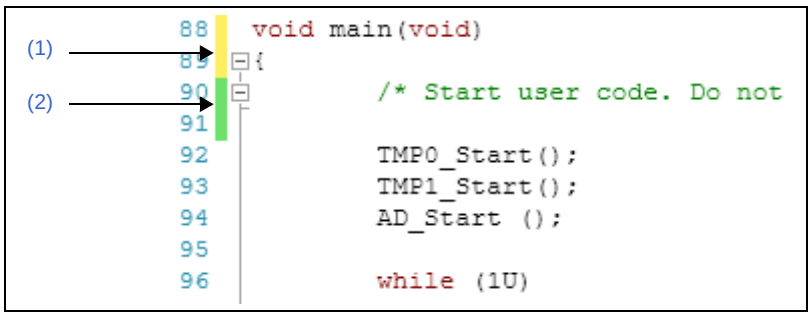


(4) Line number area

This area displays the line number of the opened text file or source file.

(5) Selection area

On each line there is an indicator that shows the line modification status.



(1)		This means new or modified line but unsaved.
(2)		This means new or modified line and saved. To erase this mark, close the panel, and then open this source file again.

(6) Main area

Bookmarks ( ) that have been registered are displayed.

```
24      void main(void)
25      {
26              /* Start user code. Do not edit comment generated here */
27
28              int local_a, local_b, local_c;
29              int result;
30              unsigned long i;
```

(7) Characters area

This area displays character strings of text files and source files and you can edit it.
This area has the following functions.

(a) Character editing

Characters can be entered from the keyboard.
Various shortcut keys can be used to enhance the edit function.

Remark The following items can be customized by setting the Option dialog box.
- Display fonts
- Tab interval
- Show or hide white space marks (blank symbols)
- Colors of reserved words and comments

(b) Code outlining

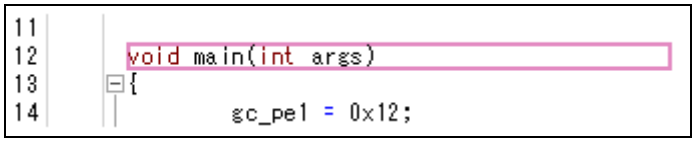
This allows you to expand and collapse source code blocks so that you can concentrate on the areas of code which you are currently modifying or debugging. This is only available for only C source file and .h file types.
This is achieved by clicking the plus and minus symbols to the left of the Characters area.
Types of source code blocks that can be expanded or collapsed are:

Open and close braces ('{' and '}')	{ ... }
Multi-line comments ('/*' and '*/')	/**/
Pre-processor statements ('if', 'elif', 'else', 'endif')	#if [Preprocessor block] #elif [Preprocessor block] #else [Preprocessor block] #endif

(c) Highlighting the current line

By selecting the [Enable line highlight for current] check box in the [General - Text Editor] category of the Option dialog box, the line at the current caret position can be displayed within a rectangle (the rectangle color depends on the highlight color in the [General - Font and Color] category of the same dialog box above).

Figure A-3. Highlighting Current Line



(d) Emphasizing brackets

The bracket that corresponds to a bracket at the caret position is shown emphasized.
Supported types of brackets vary with the file type.

File Type	Types of Brackedts
C or Python	(and), { and }, [and]
HTML or XML	< and >

Remark When CubeSuite+ emphasizes the corresponding bracket, it does not consider those within comments, character constants, character strings, or string constants. For this reason, if the bracket at the position of the caret is within a comment, character constant, character string, or string constant, CubeSuite+ may emphasize a bracket that is not actually the corresponding bracket.

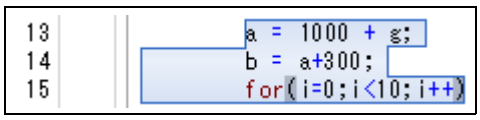
(e) Multiple lines selection and block selection

You can select multiple lines or a block that consists of multiple lines by any one of the following methods.

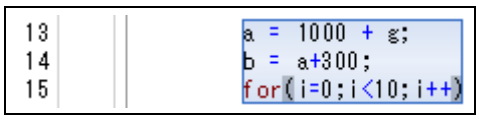
- Multiple lines selection:
  - Drag the left-mouse button
  - Press the [Right], [Left], [Up] or [Down] key while holding down the [Shift] key
- Block selection:
  - Drag the left-mouse button while holding down the [Alt] key
  - Press the [Right], [Left], [Up] or [Down] key while holding down the [Alt] + [Shift] key

Figure A-4. Multiple Lines Selection and Block Selection

[Multiple lines selection]



[Block selection]



Caution The information on bookmarks is not included in the selected contents.

Remark Editing of the selected contents can be done by using [Cut], [Copy], [Paste], or [Delete] from the [Edit] menu.

(f) Jump to functions

It automatically recognizes the currently selected characters or the word at the caret position as the function name and jumps to the line of the target function.
Select [Jump to Function] from the context menu after moving the caret to the target function on the source text.
If there are many functions with the same name, the Jump to Function dialog box is opened to select the jump destination function.
However, this function is only enabled when the setting is made to output cross reference information in the property panel of the build tool in use ([Yes(-Xcref)] is selected in [Common Options] tab >> [Output File Type and Path] category >> [Output cross reference information] property).

Note that this function is available only when the following conditions are satisfied.
Conditions differ according to the selection of the [Output cross reference information] property of the build tool.

- When [Yes(-Xcref)] is selected:
  - Build is executed and cross reference information is output.
- When [No] is selected:
  - The type of the project specified as the active project is "Application".
  - The target function is a global function.

(g) Tag jump

If the information of a file name, a line number and a column number exists in the line at the caret position, selecting [Tag Jump] from the context menu opens the file in the Editor panel and jumps to the corresponding line and the corresponding column (if the target file is already opened in the Editor panel, you can jump to the panel).

(h) Registration of bookmarks

By clicking the  button on the bookmark toolbar or selecting [Bookmark] >> [Toggle Bookmark] from the context menu on this area, a bookmark can be registered to the line at the carret position.

(i) File monitor

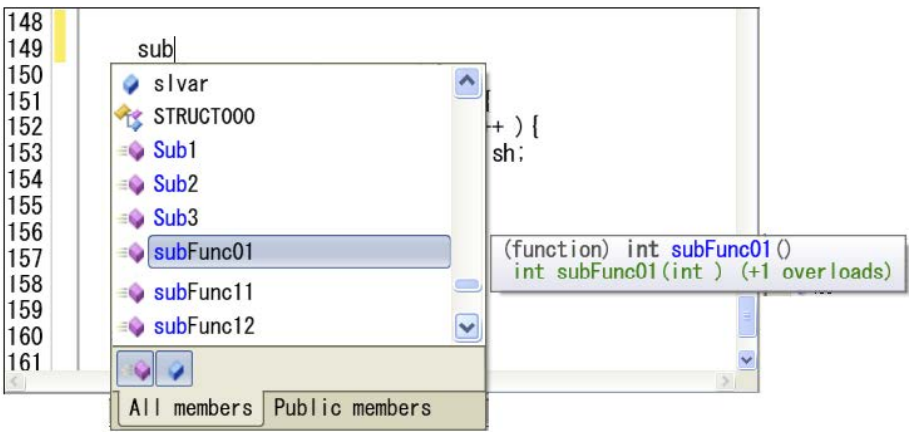
If the contents of the currently displayed file is changed (including renaming or deleting) without using CubeSuite+, a message will appear asking you whether you wish to update the file or not.

(j) Smart edit function

The smart edit function is used to complement the names of functions, variables and the arguments of functions during input and offer them as candidates.
The smart edit function complements the information listed below.

- Global functions in the C language
- Global variables in the C language

Figure A-5. Display Example of Smart Edit Function (Candidates of Function and Variables)



Follow the procedure below to enable the smart edit function.

- Select the [Emable smart editing] check box in the [General - Text Editor] category of the Option dialog box (default).
- Candidates are displayed by using the cross reference information that is generated by the build tool. Therefore, set the build tool's Property panel[Note] so that the cross reference information is output, and then run and complete a build.
  If an error in building occurs, the cross reference information before the error occured is used if any exists.

Note [Common Options] tab] >> [Output File Type and Path] category >> [Output cross reference information] property >> [Yes(-Xcref)]
If this setting is invalid, the smart edit function cannot be used since the output will be empty of the cross reference information.

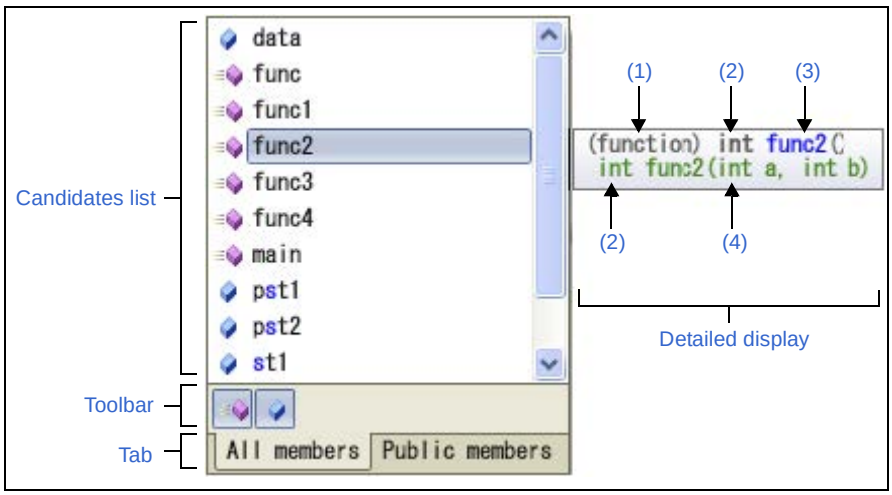
<1> Display of candidates for functions and variables

- How to display
  Candidates for functions and variables can be displayed by any one of the following methods:
  - In the C language, when "." or "->" is input if there is a relevant member for the left side
  - When the [Ctrl] + [Space] key on the keyboard is pressed (all candidates are displayed)
    However, if there is only one candidate, the relevant character string is inserted at this time without displaying the candidate.

- How to insert character strings
  Select a character string from the candidates list by using the [Up]/[Down] key or the mouse, then press the [Enter] key or the [TAB] key.

- Description of each area

Figure A-6. Display of Candidates for Functions and Variables



- Candidates list
  Displays candidates for functions and variables in alphabetical order.
  If there are character strings that match to the character strings at the caret position, they are highlighted (case insensitive).
  The following icons are displayed as labels for the list of candidates.

Icon	Description
	Shows that the candidate is for a typedef.
	Shows that the candidate is for a function.
	Shows that the candidate is for a variable.
	Shows that the candidate is for a structure.
	Shows that the candidate is for an union.
	Shows that the candidate is for an enumeration type.

- Toolbar

  Switches whether candidates for functions and variables are displayed or not.

Button	Description
	Displays candidates for functions.
	Displays candidates for variables.

- Tab

  Switches the members to be displayed.

Tab Name	Description
All members	Displays all candidates.
Public members	Displays only the candidates with the public attribute.

- Detailed display

  Displays details of candidates for functions or variables currently being selected.

Item	Description
(1) Kind	Shows whether the selected item is a function or a variable. (function) : Shows the selected item is a function. (variable) : Shows the selected item is a variable.
(2) Type	Shows the type of the function or the variable.
(3) Name	Shows the name of the function or the variable.
(4) Name and argument	Shows the name of the function or the variable. When the item is a function, its arguments are also shown.

<2> Display of candidates for arguments

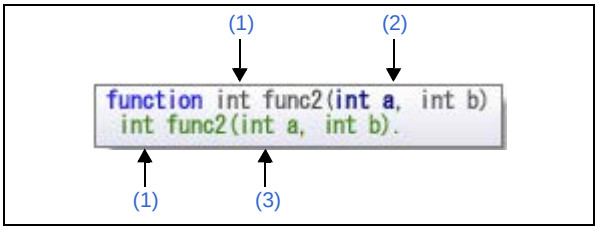
- How to display

  Candidates for arguments are displayed when:

  - In a function name, when "(" is input if there is a relevant function on the left side of "("
  - When the [Ctrl] + [Shift] + [Space] key on the keyboard is pressed while the text cursor is at the location of an argument for a function

- Description of each area

Figure A-7. Display of Candidates for Arguments



Item	Description
(1) Type	Shows the type of the function or the variable.
(2) Name and argument	Shows the name of the function and its arguments. The argument at the current caret position is highlighted.
(3) Name and argument	Shows the name of the function and its arguments.

<3> Termination of the candidates display

The candidates display disappears by any one of the following methods:

- Press the [ESC] key
- Enter a key other than an alphanumeric character

When nothing is selected from the candidates list: This operation has no effect.

When an item is selected in the candidates list: The selected character strings are inserted.

<4> Notes for displaying of candidates list

- The following items are not the subject of the candidates display.
  - Macro definitions
  - Local variables
  - Typedef statements
- When a structure or union is declared within a function, candidates are not displayed within the function after its own declaration.
- In some cases the type of variables to be displayed differs from that actually declared when a compiler option which affects the size of variables is set.

Remark When the mouse cursor is hovered over a function name or a variable name on the source text, the information about that function or variable appears in a pop-up.

Note the following, however, when using this function.

- const, static, and volatile attributes cannot be displayed in a pop-up.
- If the target is a variable of class, structure, union, or enumeration type, its members are displayed as follows:
  - If the target is a class-, structure-, or union-type variable, the types and names of its members are displayed.

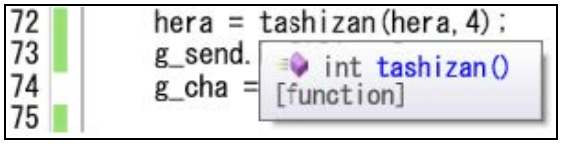
    If the target is a class-type variable that includes methods (functions) among its members, the types of the return values and names of the methods (functions) are displayed. Also, '(' ')' is appended to the end of each method name.
  - If the target is an enumeration-type variable, only the names of the members are displayed.

- Members are displayed in the same order as they are defined in the source file, and each is placed on a single line (up to 20 members can be displayed).

The meaning of each icon displayed in a pop-up is described below.

Icon	Description
	Shows that the candidate is for a typedef.
	Shows that the candidate is for a function.
	Shows that the candidate is for a variable.
	Shows that the candidate is for a structure.
	Shows that the candidate is for an union.
	Shows that the candidate is for an enumeration type.

Figure A-8. Pop-up Display of Smart Edit Function



[Toolbar]

	Toggles between normal (default) and mixed display mode, as the display mode of this panel. Note that this item is enabled only when connected to the debug tool and the downloaded source file is opened in this panel.
	Toggles between source (default) and instruction level, as the unit in which the program is step-executed. Note that this item is enabled only when connected to the debug tool and the mixed display mode is selected.
	Displays the current PC position. Note that this item is enabled only when connected to the debug tool.
	Forwards to the position before operating [Context menu] >> [Back To Last Cursor Position]. Note that this item is disabled when connected to the debug tool and the mixed display mode is selected.
	Goes back to the position before operating [Context menu] >> [Jump to Function]. Note that this item is disabled when connected to the debug tool and the mixed display mode is selected.
Columns	The following items are displayed to show or hide the columns or marks on this panel. Remove the check to hide the items (all the items are checked by default). This setting is reflected in all the Editor panels.
Line Number	Shows or hides line number area.
Selection	Shows or hides selection area.
Main	Shows or hides main area.
Column Header	Shows or hides column header.

[[File] menu (Editor panel-dedicated items)]

The following items are exclusive for the [File] menu in the Editor panel (other items are common to all the panels).

Close *file name*	Closes the currently editing the Editor panel. When the contents of the panel have not been saved, a confirmation message is shown.
Save *file name*	Overwrites the contents of the currently editing the Editor panel. Note that when the file has never been saved or the file is read only, the same operation is applied as the selection in [Save *file name* As...].
Save *file name* As...	Opens the Save As dialog box to newly save the contents of the currently editing the Editor panel.
file name Save Settings...	Opens the Save Settings dialog box to change the encoding and newline code of the current focused source file in the currently editing Editor panel.
Print...	Opens the Print dialog box of Windows for printing the contents of the currently editing the Editor panel.
Print Preview	Opens the Print Preview window to preview the file contents to be printed.

[[Edit] menu (Editor panel-dedicated items)]

The following items are exclusive for the [Edit] menu in the Editor panel (all other items are disabled).

Undo	Cancels the previous operation on the Editor panel and restores the characters and the caret position (max 100 times).
Redo	Cancels the previous [Undo] operation on the Editor panel and restores the characters and the caret position.
Cut	Cuts the selected characters and copies them to the clip board. If there is no selection, the entire line is cut.
Copy	Copies the contents of the selected range to the clipboard as character string(s). If there is no selection, the entire line is copied.
Paste	Inserts (insert mode) or overwrites (overwrite mode) the characters that are copied on the clip board into the caret position. When the contents of the clipboard are not recognized as characters, the operation is invalid. The mode selected for the current source file is displayed on the status bar.
Delete	Deletes one character at the caret position. When there is a selection area, all the characters in the area are deleted.
Select All	Selects all the characters from the beginning to the end in the currently editing text file.
Find...	Opens the Find and Replace dialog box with selecting [Quick Find] tab.
Replace...	Opens the Find and Replace dialog box with selecting [Quick Replace] tab.
Go To...	Opens the Go to Line dialog box to move the caret to the specified line.
Bookmark	Displays a cascading menu for bookmarks.
Toggle Bookmark	Registers a bookmark to the line at the current caret position. If a bookmark is already being registered to the line, then the bookmark will be deleted.
Next Bookmark	Moves the caret to the bookmark position that registered next, in the active Editor panel. After moving to the last bookmark, the caret moves to the line specified in the first bookmark.

Previous Bookmark	Moves the caret to the bookmark position that registered previously, in the active Editor panel. After moving to the first bookmark, the caret moves to the line specified in the last bookmark.
Clear All Bookmarks	Deletes all bookmarks currently being registered, in the active Editor panel.
List Bookmarks...	Opens the Bookmarks dialog box to list bookmarks currently being registered.
Outlining	Displays a cascading menu for controlling expand and collapse states of source file outlining (see "(b) Code outlining").
Collapse to Definitions	Collapses all nodes that are marked as implementation blocks (e.g. function definitions).
Toggle Outlining Expansion	Toggles the current state of the innermost outlining section in which the cursor lies when you are in a nested collapsed section.
Toggle All Outlining	Toggles the collapsed state of all outlining nodes, setting them all to the same expanded or collapsed state. If there is a mixture of collapsed and expanded nodes, all nodes will be expanded.
Stop Outlining	Stops code outlining and remove all outlining information from source files.
Start Automatic Outlining	Starts automatic code outlining and automatically displayed in supported source files.
Advanced	Displays a cascading menu for performing an advanced operation for the Editor panel.
Increase Line Indent	Increases the indentation of the current cursor line by one tab.
Decrease Line Indent	Decreases the indentation of the current cursor line by one tab.
Uncomment Lines	Removes the first set of line-comment delimiters from the start of the current cursor line, appropriate to the current language (e.g. C++). This operation will only be available when the language of the current source file has line-comment delimiters specified (e.g. C++).
Comment Lines	Places line-comment delimiters at the start of the current cursor line, appropriate to the current language (e.g. C++). This operation will only be available when the language of the current source file has line-comment delimiters specified (e.g. C++).
Convert Tabs to Spaces	Converts all tabs on the current cursor line into spaces.
Convert Spaces to Tabs	Converts each set of consecutive space characters on the current line to tab characters, but only for those sets of spaces that are at least equal to one tab size.
Tabify Selected Lines	Tabifies the current line, causing all spaces at the start of the line (prior to any text) to be converted to tabs where possible.
Untabify Selected Lines	Untabifies the current line, causing all tabs at the start of the line (prior to any text) to be converted to spaces.
Make Uppercase	Converts all letters within the selection to uppercase.
Make Lowercase	Converts all letters within the selection to lowercase.
Toggle Character Casing	Toggles the character cases (uppercase / lowercase) of all letters within the selection.
Capitalize	Capitalizes the first character of every word within the selection.
Delete Horizontal Whitespace	Deletes any excess white space either side of the cursor position, leaving only one whitespace character remaining. If there the cursor is within a word or not surrounded by whitespace, this operation will have no effect.
Trim Trailing Whitespace	Deletes any trailing whitespace that appears after the last non-whitespace character on the cursor line.
Delete Line	Completely delete the current cursor line.
Duplicate Line	Duplicates the cursor line, inserting a copy of the line immediately after the cursor line.
Delete Blank Lines	Deletes the line at the cursor if it is empty or contains only whitespace.

[[Window] menu (Editor panel-dedicated items)]

The following items are exclusive for the [Window] menu in the Editor panel (other items are common to all the panels).

Split	Splits the active Editor panel horizontally. Only the active Editor panel can be split. Other panels will not be split. A panel can be split up to two times.
Remove Split	Removes the split view of the Editor panel.

[Context menu]

[Title bar area]

Close Panel	Close the currently selected panel.
Close All but This	Except for the currently selected panel, close all other panels being displayed in the same panel display area as the selected panel.
Save *file name*	Saves the contents of the file.
Copy Full Path	Copies the absolute path of the file to the clipboard.
Open Containing Folder	Opens the folder where the text file is saved in Explorer.
New Horizontal Tab Group	The area for the display of active panels is evenly divided into two areas in the horizontal direction, and the panels are displayed as a new group of tabbed pages. Only one panel is active in the new group. The area may be divided into up to four panels. This item is not displayed in the following cases. - Only one panel is open. - The group has already been divided in the vertical direction. - The group has already been divided into four panels.
New Vertical Tab Group	The area for the display of active panels is evenly divided into two areas in the vertical direction, and the panels are displayed as a new group of tabbed pages. Only one panel is active in the new group. The area may be divided into up to four panels. This item is not displayed in the following cases. - Only one panel is open. - The group has already been divided in the horizontal direction. - The group has already been divided into four panels.
Go to Next Tab Group	When the display area is divided in the horizontal direction, this moves the displayed panel to the group under that displaying the selected panel. When the display area is divided in the vertical direction, this moves the displayed panel to the group to the right of that displaying the selected panel. This item is not displayed if there is no group in the given direction.
Go to Previous Tab Group	When the display area is divided in the horizontal direction, this moves the displayed panel to the group over that displaying the selected panel. When the display area is divided in the vertical direction, this moves the displayed panel to the group to the left of that displaying the selected panel. This item is not displayed if there is no group in the given direction.

[Characters area]

Cut	Cuts the selected character string and copies it to the clipboard. If there is no selection, the entire line is cut.

Copy	Copies the contents of the selected range to the clipboard as character string(s). If there is no selection, the entire line is copied.
Paste	Inserts (insert mode) or overwrites (overwrite mode) the characters that are copied on the clip board into the caret position. When the contents of the clipboard are not recognized as characters, the operation is invalid. The mode selected for the current source file is displayed on the status bar.
Find...	Opens the Find and Replace dialog box with selecting [Quick Find] tab.
Go To...	Opens the Go to Line dialog box to move the caret to the specified line.
Jump to Function	Jumps to the function that is selected or at the caret position regarding the selected characters and the words at the caret position as functions (see "(f) Jump to functions").
Tag Jump	Jumps to the corresponding line and column in the corresponding file if the information of a file name, a line number and a column number exists in the line at the caret position (see "(g) Tag jump").
Bookmark	Displays a cascading menu for bookmarks.
Toggle Bookmark	Registers a bookmark to the line at the current caret position. If a bookmark is already being registered to the line, then the bookmark will be deleted.
Next Bookmark	Moves the caret to the bookmark position that registered next, in the active Editor panel. After moving to the last bookmark, the caret moves to the line specified in the first bookmark.
Previous Bookmark	Moves the caret to the bookmark position that registered previously, in the active Editor panel. After moving to the first bookmark, the caret moves to the line specified in the last bookmark.
Clear All Bookmarks	Deletes all bookmarks currently being registered, in the active Editor panel.
List Bookmarks...	Opens the Bookmarks dialog box to list bookmarks currently being registered.
Advanced	Displays a cascading menu for performing an advanced operation for the Editor panel.
Increase Line Indent	Increases the indentation of the current cursor line by one tab.
Decrease Line Indent	Decreases the indentation of the current cursor line by one tab.
Uncomment Lines	Removes the first set of line-comment delimiters from the start of the current cursor line, appropriate to the current language (e.g. C++). This operation will only be available when the language of the current source file has line-comment delimiters specified (e.g. C++).
Comment Lines	Places line-comment delimiters at the start of the current cursor line, appropriate to the current language (e.g. C++). This operation will only be available when the language of the current source file has line-comment delimiters specified (e.g. C++).
Convert Tabs to Spaces	Converts all tabs on the current cursor line into spaces.
Convert Spaces to Tabs	Converts each set of consecutive space characters on the current line to tab characters, but only for those sets of spaces that are at least equal to one tab size.
Tabify Selected Lines	Tabifies the current line, causing all spaces at the start of the line (prior to any text) to be converted to tabs where possible.
Untabify Selected Lines	Untabifies the current line, causing all tabs at the start of the line (prior to any text) to be converted to spaces.
Make Uppercase	Converts all letters within the selection to uppercase.
Make Lowercase	Converts all letters within the selection to lowercase.
Toggle Character Casing	Toggles the character cases (uppercase / lowercase) of all letters within the selection.

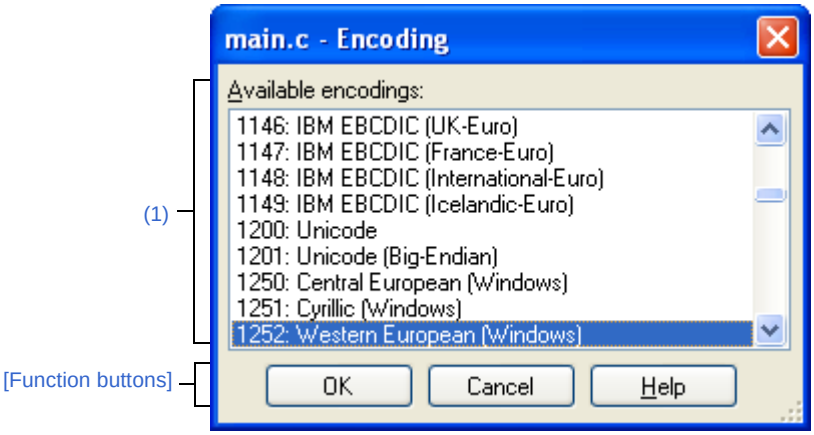
Capitalize	Capitalizes the first character of every word within the selection.
Delete Horizontal Whitespace	Deletes any excess white space either side of the cursor position, leaving only one whitespace character remaining. If there the cursor is within a word or not surrounded by whitespace, this operation will have no effect.
Trim Trailing Whitespace	Deletes any trailing whitespace that appears after the last non-whitespace character on the cursor line.
Delete Line	Completely delete the current cursor line.
Duplicate Line	Duplicates the cursor line, inserting a copy of the line immediately after the cursor line.
Delete Blank Lines	Deletes the line at the cursor if it is empty or contains only whitespace.

Encoding dialog box

This dialog box is used to select a file-encoding.

Remark The target file name is displayed on the title bar.

Figure A-9. Encoding Dialog Box



The following items are explained here.

- [How to open]
- [Description of each area]
- [Function buttons]

[How to open]

- From the [File] menu, open the Open File dialog box by selecting [Open with Encoding...], and then click the [Open] button in the dialog box.

[Description of each area]

(1) [Available encodings] area

Select the encoding to be set from this area.

The encoding of the selected file is selected by default.

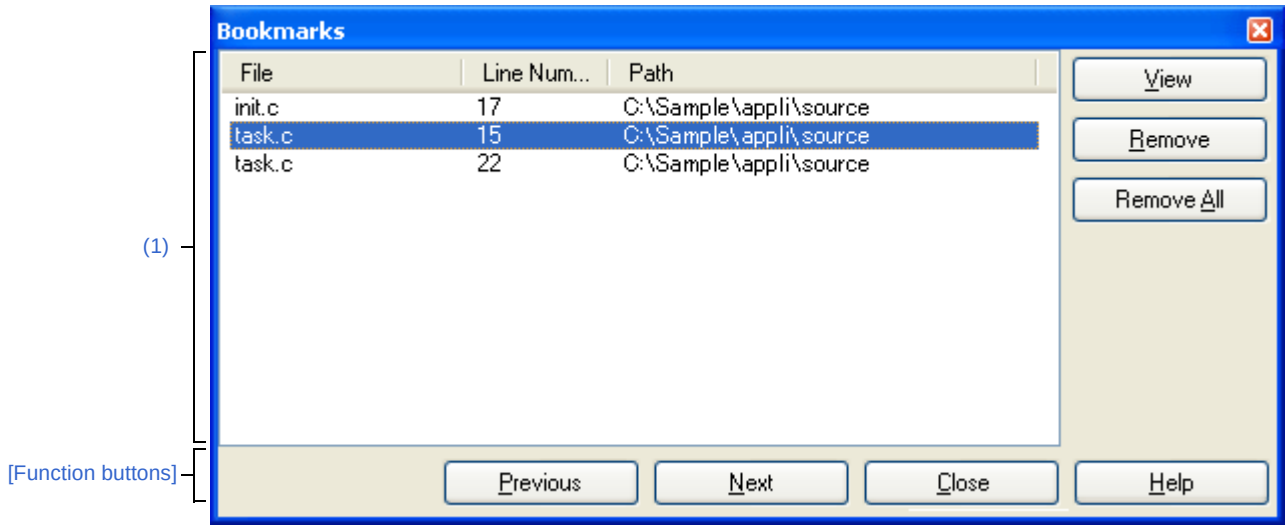
[Function buttons]

Button	Function
OK	Opens the selected file in the Open File dialog box using a selected file encoding.
Cancel	Not open the selected file in the Open File dialog box and closes this dialog box.
Help	Displays the help for this dialog box.

Bookmarks dialog box

This dialog box is used to display the position where a bookmark is to be set or to delete a bookmark.

Figure A-10. Bookmarks Dialog Box



The following items are explained here.

- [How to open]
- [Description of each area]
- [Function buttons]

[How to open]

- On the toolbar, click the  .
- From the [Edit] menu, select [Bookmark] >> [List Bookmarks...].
- On the Editor panel, select [Bookmark] >> [List Bookmarks...] from the context menu.

[Description of each area]

(1) Bookmark list area

Display a list of bookmarks that have been registered.
The bookmarks are listed alphabetically by [File]. Bookmarks in the same file are listed in line number order.
When a bookmark is added to the Editor panel, a bookmark function is added.
In the bookmark list area, double-clicking on a line moves a caret to the corresponding position for the bookmark.

(a) [File]

Display a file name (without any path) registered as a bookmark.

(b) [Line Number]

Display a line number registered as a bookmark.

(c) [Path]

Display a file path registered as a bookmark.

(d) Buttons

View	Moves a caret to the selected position for the bookmark. However, this button is disabled when no bookmark is selected, two or more bookmarks are selected, or no bookmark is registered.
Remove	Removes a selected bookmark. When two or more bookmarks are selected, all of those selected are removed. However, this button is disabled when no bookmark is selected or no bookmark is registered.
Remove All	Removes all the registered bookmarks. This button is disabled when no bookmark is registered.

Caution The registered bookmarks are not removed even if the Editor panel is closed. However, when the Editor panel is closed without saving after a file is newly created, the registered bookmarks are removed.

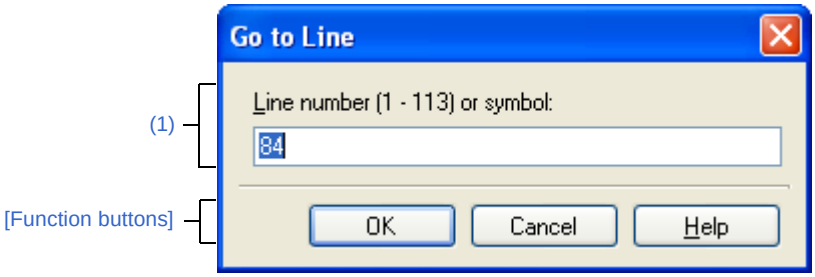
[Function buttons]

Button	Function
Previous	Moves a caret to the position of the bookmark previous to the selected bookmark. This button is disabled in the following cases. - A bookmark shown in the first line has been selected. - No bookmark is selected. - Two or more bookmarks are selected. - No bookmark is registered. - Only one bookmark is registered.
Next	Moves a caret to the position of the bookmark next to the selected bookmark. This button is disabled in the following cases. - A bookmark shown in the last line has been selected. - No bookmark is selected. - Two or more bookmarks are selected. - No bookmark is registered. - Only one bookmark is registered.
Close	Closes this dialog box.
Help	Displays the help for this dialog box.

Go to Line dialog box

This dialog box is used to move the caret to a specified line number, symbol, or address.

Figure A-11. Go to Line Dialog Box



The following items are explained here.

- [How to open]
- [Description of each area]
- [Function buttons]

[How to open]

- From the [Edit] menu, select [Go To...].
- On the Editor panel, select [Go To...] from the context menu.

[Description of each area]

(1) [Line number (*valid line range*) or symbol] area

"(*valid line range*)" shows the range of valid lines in the current file.
Specify the line number, symbol, or address that you want to move the caret to.
By default, the number of the line where the caret is currently located in the Editor panel is displayed.

Remarks 1. When a symbol (function name and variable name) is specified, building must have been completed.
The cross reference information must also be output. In the property panel of the build tool in use, after selecting the setting to output cross reference information ([Common Options] tab >> [Output File Type and Path] category >> [Output cross reference information] property >> [Yes (-Xcref)]), execute a build.

2. When an address is specified, building must have been completed.
An address can be specified with a hexadecimal starting with "0x" or "0X". A decimal is interpreted as a line number.

[Function buttons]

Button	Function
OK	Places the caret at the start of the specified source line.
Cancel	Cancels the jump and closes this dialog box.
Help	Displays the help for this dialog box.

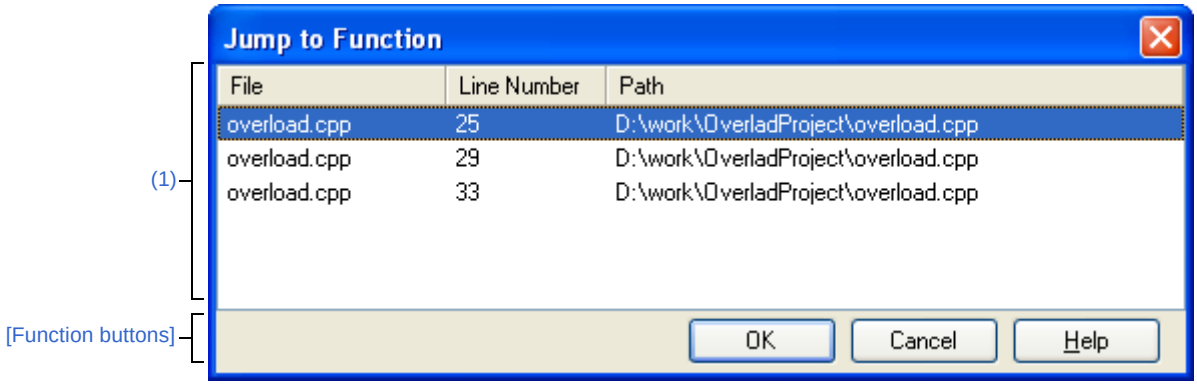
Jump to Function dialog box

This dialog box is used to select a function to be jumped if there are some functions with the same names when a program jumps to the function specified on the Editor panel.

Remarks 1. This dialog box is displayed only when there are some functions with the same names and [Yes (-Xcref)] is selected in the [Common Options] tab >> [Output File Type and Path] category >> [Output cross reference information] property of the build tool to be used.

2. This dialog box targets only files that have been registered in the project.

Figure A-12. Jump to Function Dialog Box



The following items are explained here.

- [How to open]
- [Description of each area]
- [Function buttons]

[How to open]

- On the Editor panel, select [Jump to Function] from the context menu.

[Description of each area]

(1) Candidates in the jump destination display area

List candidates in the jump destination.

Candidates are displayed in the alphabetical order of the names of [File]. If candidates are included in the same file, they are displayed in the order of line numbers.

(a) [File]

Display a file name (without any path) that a function is defined.

(b) [Line Number]

Display a line number that a function is defined.

(c) [Path]

Display a file path that a function is defined.

[Function buttons]

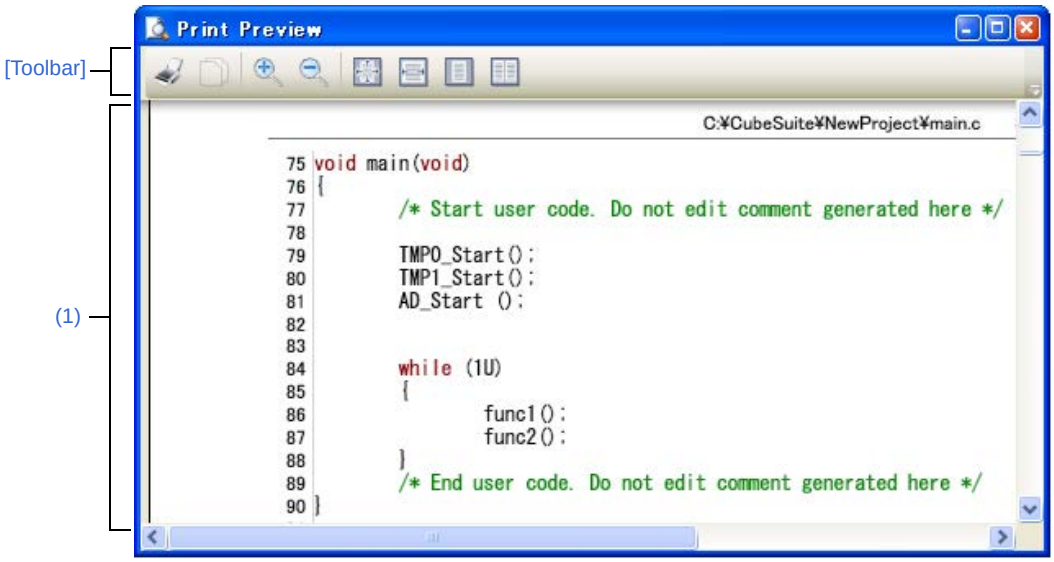
Button	Function
OK	Jumps to the line that defines the target function after selecting the line in "Candidates in the jump destination display area" and clicking this button.
Cancel	Cancels the jump and closes this dialog box.
Help	Displays the help for this dialog box.

Print Preview window

This window is used to preview the file currently being displayed in the Editor panel before printing.

Remark This window can be zoomed in and out by moving the mouse wheel forward or backward while holding down the [Ctrl] key.

Figure A-13. Print Preview Window



The following items are explained here.

- [How to open]
- [Description of each area]
- [Toolbar]
- [Context menu]

[How to open]

- Focus the Editor panel, and then select [Print Preview] from the [File] menu.

[Description of each area]

(1) Preview area

This window displays a form showing a preview of how and what is printed.
The file name (fully qualified path) and the page number are displayed at the page header and page footer.
The display differs according to whether the debug tool is or is not connected, and when it is connected, to whether the display is in normal display mode or mixed display mode. Note, however, that columns that are hidden on the Editor panel are not displayed (these columns are not printed).
When the outline setting is in used and the collapsed section mark of an outline (see "(b) Code outlining") is displayed in a print preview, the lines in the collapsed section are also displayed.

[Toolbar]

	Opens the Print dialog box provided by Windows to print the current Editor panel as shown by the print preview form.
	Copies the selection into the clipboard.
	Increases the size of the content.
	Decreases the size of the content.
	Displays the preview at 100-percent zoom (default).
	Fits the preview to the width of this window.
	Displays the whole page.
	Displays facing pages.

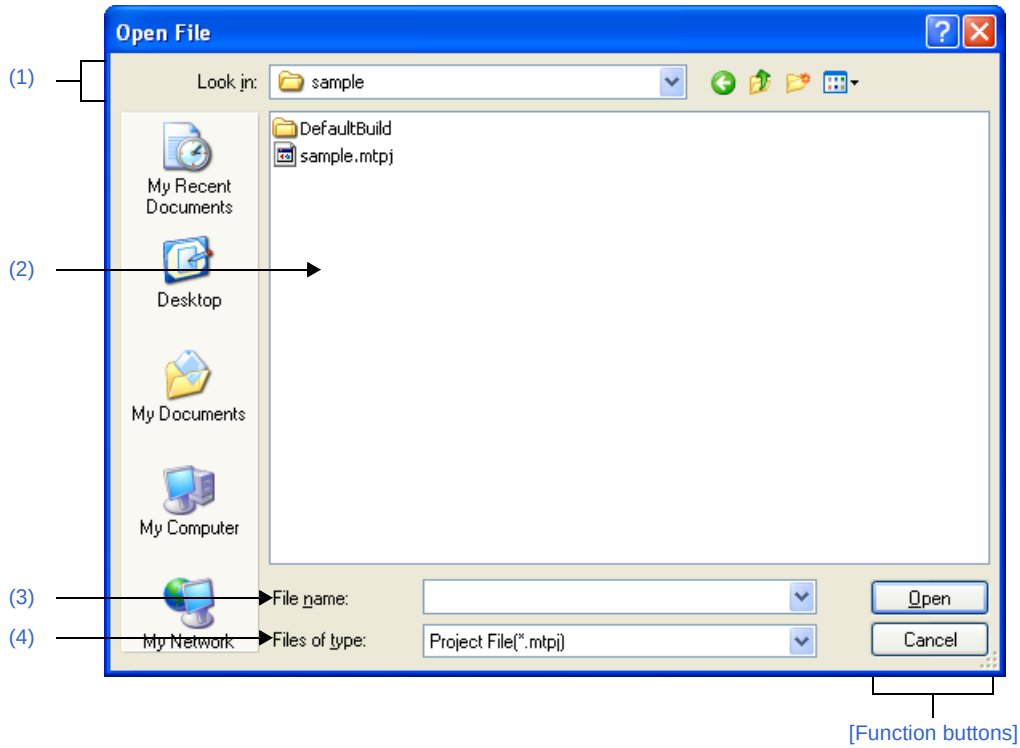
[Context menu]

Increase Zoom	Increases the size of the content.
Decrease Zoom	Decreases the size of the content.

Open File dialog box

This dialog box is used to open a file.

Figure A-14. Open File Dialog Box



The following items are explained here.

- [How to open]
- [Description of each area]
- [Function buttons]

[How to open]

- From the [File] menu, select [Open File...] or [Open with Encoding...].

[Description of each area]

(1) [Look in] area

Select the folder that the file you want to open exists.

When you first open this dialog box, the folder is set to "C:\Documents and Settings *user-name*\My Documents".

The second and subsequent times, this defaults to the last folder that was selected.

(2) List of files area

File list that matches to the selections in [Look in] and [Files of type] is shown.

(3) [File name] area

Specify the file name that you want to open.

(4) [Files of type] area

Select the type of the file you want to open.

All files (*.*)	All formats
Project File (*.mtpj)	Project file
Project File for e2 studio (*.rcpc)	Project file for e^2 studio
Project File for CubeSuite (*.cspj)	Project file for CubeSuite
Workspace File for HEW (*.hws)	Workspace file for HEW
Project File for HEW (*.hwp)	Project file for HEW
Workspace File for PM+ (*.prw)	Workspace file for PM+
Project File for PM+ (*.prj)	Project file for PM+
C source file (*.c)	C language source file
Header file (*.h; *.inc)	Header file
Assembly source file (*.asm; *.s; *.fsy)	Assembler source file
Link Map file (*.map; *.lbp)	Link Map file
Stack information file (*.sni)	Stack information file
Intel HEX file (*.hex)	Intel HEX file
Motorola S-record file (*.mot)	Motorola S-record file
Text file (*.txt)	Text format

[Function buttons]

Button	Function
Open	- When this dialog box is opened by [Open File...] from the [File] menu Opens the specified file. - When this dialog box is opened by [Open File with Encoding...] from the [File] menu Opens the Encoding dialog box.
Cancel	Closes this dialog box.

APPENDIX B INDEX

Symbols

< operator ... 124
<= operator ... 125
<< operator ... 130
! operator ... 115
!= operator ... 121
#pragma directive ... 52
% operator ... 111
& operator ... 116
&& operator ... 126
== operator ... 120
> operator ... 122
>= operator ... 123
>> operator ... 129
^ operator ... 118
| operator ... 117
|| operator ... 127

Numerics

2-byte separation operator ... 134

A

abort ... 612
abs ... 585
absf.d ... 422
absf.s ... 423
absolute expression ... 145
acos ... 650
acosf ... 649
add ... 248
addf.d ... 424
addf.s ... 425
addi ... 250
adf ... 253
.align directive ... 180
alignment condition ... 45
and ... 322
andi ... 324
arithmetic operation instructions ... 247
arithmetic operator ... 106
array type ... 42
asin ... 652
asinf ... 651
assembler control instruction ... 198
assembler generated symbols ... 221
assembly language specifications ... 95
    assembler generated symbols ... 221
    control instructions ... 197
    description of source ... 95
    directives ... 147
    macro ... 218
    reserved words ... 220
assert ... 507
assert.h ... 504
atan ... 654
atan2 ... 656
atan2f ... 655
atanf ... 653
atof ... 602
atoff ... 601
atoi ... 593
atol ... 594
atoll ... 595

B

basic language specifications ... 24
    C99 language function ... 37
    internal representation and value area of data ... 40
    Option to process in strict accordance with ANSI standard ... 39
    processing system dependent items ... 27
    register mode ... 49
    section name ... 48
    undefined behavior ... 25
    unspecified behavior ... 24
binary ... 101

BINCLUDE control instruction ... 208
bins ... 299
BIT ... 99
bit field ... 44
bit manipulation instructions ... 366
Bookmarks dialog box ... 730
branch instructions ... 346
bsearch ... 588
bsh ... 336
.bss ... 99
bsw ... 337
byte separation operator ... 131

C

C99 language functionr ... 37
calloc ... 605
callt ... 398
caxi ... 400
CC-RH ... 9
ceil ... 630
ceilf ... 629
ceilf.dl ... 448
ceilf.dul ... 450
ceilf.duw ... 451
ceilf.dw ... 449
ceilf.sl ... 452
ceilf.sul ... 454
ceilf.suw ... 455
ceilf.sw ... 453
character classification functions ... 537
character constants ... 101
character conversion functions ... 534
character string constant ... 102
character string functions ... 512
cll ... 387
clr1 ... 369
cmov ... 291
cmovf.d ... 496
cmovf.s ... 497
cmp ... 283
cmpf.d ... 492
cmpf.s ... 494
comment ... 103
compiler generated symbols ... 52
compiler language specifications ... 24
    basic language specifications ... 24
    extended language specifications ... 51
compiler output directives ... 161
concatenation ... 219
conditional assembly control instruction ... 209
.const ... 98
constant ... 100
control instructions ... 197
    asembler control instruction ... 198
    conditional assembly control instruction ... 209
    file input control instruction ... 206
cos ... 644
cosf ... 643
cosh ... 658
coshf ... 657
.cseg directive ... 149
ctret ... 399
ctype.h ... 504
cvtf.dl ... 456
cvtf.ds ... 457
cvtf.dul ... 458
cvtf.duw ... 459
cvtf.dw ... 460
cvtf.hs ... 461
cvtf.ld ... 462
cvtf.ls ... 463
cvtf.sd ... 464
cvtf.sh ... 465
cvtf.sl ... 466
cvtf.sul ... 467
cvtf.suw ... 468
cvtf.sw ... 469
cvtf.uld ... 470
cvtf.uls ... 471
cvtf.uwd ... 472
cvtf.uws ... 473
cvtf.wd ... 474

cvtf.ws ... 475

D

.data ... 99
DATA control instruction ... 202
data definition, area reservation directives ... 167
.db directive ... 168
.db2 directive ... 170
.db4 directive ... 173
.db8 directive ... 175
.ddw directive ... 175
decimal ... 101
.dhw directive ... 170
di ... 388
directives ... 147
  compiler output directives ... 161
  data definition, area reservation directives ... 167
  external definition, external reference directives ... 181
  macro directives ... 185
  section definition directive ... 148
  symbol definition directives ... 158
dispose ... 409
div ... 275, 590
divf.d ... 426
divf.s ... 427
divh ... 271
divhu ... 277
divq ... 281
divqu ... 282
divu ... 279
dollar symbol ... 220
.double directive ... 178
.ds directive ... 179
.dseg directive ... 151
.dshw directive ... 172
.dw directive ... 173

E

.ebss ... 99
.ebss23 ... 99
.edata ... 99
.edata23 ... 99
Editor panel ... 714
ei ... 389
eiret ... 391
element pointer ... 694
ELSEIF control instruction ... 214
ELSEIFN control instruction ... 215
Encoding dialog box ... 729
ENDIF control instruction ... 217
.endm directive ... 195
enumerate type ... 42
ep ... 694
.equ directive ... 160
errno.h ... 504
.exitm directive ... 193
.exitma directive ... 194
exp ... 620
expf ... 619
expression ... 104
  absolute expression ... 145
  relative expressions ... 146
extended language specifications ... 51
  #pragma directive ... 52
  compiler generated symbols ... 52
  macro name ... 51
  reserved words ... 52
.extern directive ... 184
external definition, external reference directives ... 181

F

fabs ... 632
fabsf ... 631
feret ... 392
fetrap ... 395
fgetc ... 553
fgets ... 554
.file directive ... 162
file input control instruction ... 206
.float directive ... 177
float.h ... 505

floating-point operation instructions ... 419
floating-point type ... 41
floor ... 634
floorf ... 633
floorf.dl ... 476
floorf.dul ... 478
floorf.duw ... 479
floorf.dw ... 477
floorf.sl ... 480
floorf.sul ... 482
floorf.suw ... 483
floorf.sw ... 481
fmaf.s ... 444
fmod ... 636
fmodf ... 635
fmsf.s ... 445
fnmaf.s ... 446
fnmsf.s ... 447
fprintf ... 566
fputc ... 557
fputs ... 558
fread ... 551
free ... 609
frexp ... 638
frexpf ... 637
fscanf ... 579
function call interface ... 701
functions with variable arguments ... 508
fwrite ... 555

G

general-purpose registers ... 709
getc ... 552
getchar ... 559
gets ... 560
global pointer ... 692
Go to Line dialog box ... 732
gp ... 692

H

halt ... 393
_h_c_lib.h ... 505
hdwinit ... 667
header files ... 504
hexadecimal ... 101
HIGH operator ... 132
HIGHW operator ... 135
HIGHW1 operator ... 137
hsh ... 338
hsw ... 339

I

IF control instruction ... 212
IFDEF control instruction ... 210
IFN control instruction ... 213
IFNDEF control instruction ... 211
INCLUDE control instruction ... 207
initialization peripheral devices function ... 666
_INITSCT_RH ... 664
instruction set ... 222
  arithmetic operation instructions ... 247
  bit manipulation instructions ... 366
  branch instructions ... 346
  floating-point operation instructions ... 419
  load/store instructions ... 235
  logical instructions ... 311
  loop instructions ... 416
  other instructions ... 499
  saturated operation instructions ... 301
  special instructions ... 380
  stack manipulation instructions ... 375
integer type ... 40
internal representation and value area of data ... 40
  alignment condition ... 45
  array type ... 42
  bit field ... 44
  enumerate type ... 42
  floating-point type ... 41
  integer type ... 40
  pointer type ... 42
  structure type ... 43
  union type ... 43

.irp directive ... 191
IRP-ENDM block ... 191
isalnum ... 538
isalpha ... 539
isascii ... 540
iscntrl ... 545
isdigit ... 543
isgraph ... 549
islower ... 542
isprint ... 548
ispunct ... 546
isspace ... 547
isupper ... 541
isxdigit ... 544

J

jarl ... 361
jarl22 ... 363
jarl32 ... 365
jcnd ... 354
jcnd17 ... 359
jcnd9 ... 357
jmp ... 347
jmp32 ... 348
jr22 ... 351
jr32 ... 353
Jump to Function dialog box ... 733

L

label ... 97
labs ... 586
ld ... 236
ld23 ... 240
ldexp ... 640
ldexpf ... 639
ldiv ... 591
ldl.w ... 385
ldsr ... 381
library function ... 506
  character classification functions ... 537
  character conversion functions ... 534
  character string functions ... 512
  functions with variable arguments ... 508
  initialization peripheral devices function ... 666
  mathematical functions ... 617
  memory management functions ... 528
  non-local jump functions ... 613
  program diagnostic function ... 506
  RAM section initialization function ... 663
  standard I/O functions ... 550
  standard utility functions ... 584
limits.h ... 505
.line directive ... 163
._line_end directive ... 166
._line_top directive ... 165
llabs ... 587
lldiv ... 592
load/store instructions ... 235
.local directive ... 188
log ... 622
log10 ... 624
log10f ... 623
logf ... 621
logic operator ... 114
logical instructions ... 311
longjmp ... 614
loop ... 417
loop instructions ... 416
LOW operator ... 133
LOWW operator ... 136

M

mac ... 269
macro ... 218
  macro operator ... 219
MACRO control instruction ... 201
.macro directive ... 186
macro directives ... 185
macro name ... 51, 97
macro operator ... 219
macu ... 270
malloc ... 607

mathematical functions ... 617
mathf.h ... 505
math.h ... 505
maxf.d ... 428
maxf.s ... 429
memchr ... 529
memcmp ... 530
memcpy ... 531
memmove ... 532
memory management functions ... 528
memset ... 533
minf.d ... 430
minf.s ... 431
mnemonic field ... 100
modf ... 642
modff ... 641
mov ... 285
mov32 ... 290
movea ... 287
movhi ... 289
mul ... 265
mulf.d ... 432
mulf.s ... 433
mulh ... 261
mulhi ... 263
mulu ... 267

N

name ... 97
negf.d ... 434
negf.s ... 435
NOMACRO control instruction ... 200
non-local jump functions ... 613
nop ... 396
not ... 327
not1 ... 371
NOWARNING control instruction ... 204
numeric constant ... 100

O

octal ... 101
.offset directive ... 157
Open File dialog box ... 737
operand field ... 100
operator ... 104
Option to process in strict accordance with ANSI standard ... 39
or ... 312
.org directive ... 156
ori ... 314
other instructions ... 499
other operator ... 143

P

perror ... 583
pointer type ... 42
pop ... 378
popm ... 379
popsp ... 414
pow ... 626
powf ... 625
prepare ... 406
Print Preview window ... 735
printf ... 569
processing system dependent items ... 27
program diagnostic function ... 506
.public directive ... 182
push ... 376
pushm ... 377
pushsp ... 413
putc ... 556
putchar ... 561
puts ... 562

Q

qsort ... 589

R

RAM section initialization function ... 663
rand ... 610
realloc ... 608
recipf.d ... 436
recipf.s ... 437

re-entrant ... 505
register mode ... 49
REG_MODE control instruction ... 199
relative expressions ... 146
relocation attribute ... 149, 151
.rept directive ... 190
REPT-ENDM block ... 190
reserved words ... 52, 220
reti ... 390
rewind ... 582
rie ... 401
rotl ... 300
rsqrtf.d ... 438
rsqrtf.s ... 439

S

sar ... 330
sasf ... 297
satadd ... 302
satsub ... 305
satsubi ... 307
satsubr ... 309
saturated operation instructions ... 301
sbf ... 259
.sbss ... 99
.sbss23 ... 99
scanf ... 580
sch0l ... 342
sch0r ... 343
sch1l ... 344
sch1r ... 345
.sdata ... 99
SDATA control instruction ... 203
.sdata23 ... 99
section ... 500
section allocation ... 500
section definition directive ... 148
.section directive ... 155
section name ... 48
section aggregation operator ... 138
set1 ... 367
.set directive ... 159
setf ... 295
setjmp ... 616
setjmp.h ... 505
shift operator ... 128
shl ... 331
shr ... 329
sin ... 646
sinf ... 645
sinh ... 660
sinhf ... 659
sld ... 238
smart edit function ... 719
snooze ... 415
special instructions ... 380
sprintf ... 563
sqrt ... 628
sqrtf ... 627
sqrtf.d ... 440
sqrtf.s ... 441
srand ... 611
sscanf ... 575
sst ... 244
st ... 242
st23 ... 245
.stack directive ... 164
stack manipulation instructions ... 375
standard I/O functions ... 550
standard utility functions ... 584
startup ... 670
startup routine ... 670
stc.w ... 386
stdarg.h ... 505
stddef.h ... 505
stdio.h ... 505
stdlib.h ... 505
strcat ... 523
strchr ... 515
strcmp ... 519
strcpy ... 521
strcspn ... 518

strerror ... 527
string.h ... 505
strlen ... 526
strncat ... 524
strncmp ... 520
strncpy ... 522
strpbrk ... 513
strrchr ... 514
strspn ... 517
strstr ... 516
strtod ... 604
strtodf ... 603
strtok ... 525
strtol ... 596
strtoll ... 599
strtoul ... 598
strtoull ... 600
structure type ... 43
stsr ... 383
sub ... 255
subf.d ... 442
subf.s ... 443
subr ... 257
supplied libraries ... 504
switch ... 397
sxb ... 332
sxh ... 333
symbol attribute ... 99
symbol definition directives ... 158
synce ... 404
synci ... 405
syncm ... 402
syncp ... 403
syscall ... 411

T

tag jump ... 719
tan ... 648
tanf ... 647
tanh ... 662
tanhf ... 661
.tbss4 ... 99
.tbss5 ... 99
.tbss7 ... 99
.tbss8 ... 99
.tdata ... 99
.tdata4 ... 99
.tdata5 ... 99
.tdata7 ... 99
.tdata8 ... 99
.text ... 98
tolower ... 536
toupper ... 535
trap ... 394
trfsr ... 498
trncf.dl ... 484
trncf.dul ... 485
trncf.duw ... 486
trncf.dw ... 487
trncf.sl ... 488
trncf.sul ... 489
trncf.suw ... 490
trncf.sw ... 491
tst ... 340
tst1 ... 373

U

undefined behavior ... 25
ungetc ... 581
union type ... 43
unspecified behavior ... 24

V

va_arg ... 511
va_end ... 510
va_start ... 509
vfprintf ... 571
vprintf ... 573
vsprintf ... 568

W

WARNING control instruction ... 205

X

xor ... 317
xori ... 319

Z

.zbss ... 99
.zbss23 ... 99
.zconst ... 98
.zconst23 ... 98
.zdata ... 99
.zdata23 ... 99
zxb ... 334
zxh ... 335

Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Apr 01, 2013	-	First Edition issued
1.01	Sep 01, 2013	**357 - 358**	[4.8.5 Branch instructions] "jcnd9" added.
		504	[6.1 Supplied Libraries] Modified to "However, it is not necessary to refer the libraries if only "function with a variable arguments", "character conversion functions" and "character classification functions" are used." -> "However, it is not necessary to refer the libraries if only "program diagnosis function", "function with a variable arguments", "character conversion functions" and "character classification functions" are used."
		605, 607, 608	[calloc], [malloc], [realloc] [Heap memory setup example] in [Caution] modified.
		670 - 691	[7.1 Outline] - [7.3 Coding Example] All sections revised.
		713 - 728, 730 - 734, 737 -738	[APPENDIX A WINDOW REFERENCE] A part of descriptions modified of "Editor panel", "Bookmarks dialog box", "Go to Line dialog box", "Open File dialog box". "Jump to Function dialog box" added.

CubeSuite+ V2.01.00 User's Manual:
RH850 Coding

Publication Date: Rev.1.00 Apr 01, 2013
Rev.1.01 Sep 01, 2013

Published by: Renesas Electronics Corporation

SALES OFFICES Renesas Electronics Corporation http://www.renesas.com

Refer to "http://www.renesas.com/" for the latest and detailed information.

Renesas Electronics America Inc.
2880 Scott Boulevard Santa Clara, CA 95050-2554, U.S.A.
Tel: +1-408-588-6000, Fax: +1-408-588-6130

Renesas Electronics Canada Limited
1101 Nicholson Road, Newmarket, Ontario L3Y 9C3, Canada
Tel: +1-905-898-5441, Fax: +1-905-898-3220

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-65030, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
7th Floor, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100083, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 204, 205, AZIA Center, No.1233 Lujiazui Ring Rd., Pudong District, Shanghai 200120, China
Tel: +86-21-5877-1818, Fax: +86-21-6887-7858 / -7898

Renesas Electronics Hong Kong Limited
Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2886-9318, Fax: +852 2886-9022/9044

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics Korea Co., Ltd.
11F., Samik Lavied' or Bldg., 720-2 Yeoksam-Dong, Kangnam-Ku, Seoul 135-080, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141

Colophon 1.3

CubeSuite+ V2.01.00

Renesas Electronics Corporation

R20UT2584EJ0101