IAR Embedded Workbench

IAR C/C++ Development Guide

Compiling and linking

for the Renesas

RH850 Family

DRH850-4

IAR SYSTEMS

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EDITION NOTICE
Fourth edition: April 2020

Part number: DRH850-4

This guide applies to version 2.x of IAR Embedded Workbench® for the Renesas RH850 Family.

Internal reference: BB6, Mym8.4, csrct2010.1, V_110411, IJOA.

Brief contents

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Preface

Welcome to the *IAR C/C++ Development Guide for RH850*. The purpose of this guide is to provide you with detailed reference information that can help you to use the build tools to best suit your application requirements. This guide also gives you suggestions on coding techniques so that you can develop applications with maximum efficiency.

Who should read this guide

Read this guide if you plan to develop an application using the C or C++ language for the RH850 microcontroller, and need detailed reference information on how to use the build tools.

REQUIRED KNOWLEDGE

To use the tools in IAR Embedded Workbench, you should have working knowledge of:

- The architecture and instruction set of the RH850 microcontroller (refer to the chip manufacturer's documentation)
- The C or C++ programming language
- Application development for embedded systems
- The operating system of your host computer.

For more information about the other development tools incorporated in the IDE, refer to their respective documentation, see *Other documentation*, page 39.

How to use this guide

When you start using the IAR C/C++ compiler and linker for RH850, you should read *Part 1. Using the build tools* in this guide.

When you are familiar with the compiler and linker, and have already configured your project, you can focus more on *Part 2. Reference information*.

If you are new to using this product, we suggest that you first go through the tutorials, which you can find in IAR Information Center in the product. They will help you get started using IAR Embedded Workbench.

What this guide contains

Below is a brief outline and summary of the chapters in this guide.

PART 1. USING THE BUILD TOOLS

- *Introduction to the IAR build tools* gives an introduction to the IAR build tools, which includes an overview of the tools, the programming languages, the available device support, and extensions provided for supporting specific features of the RH850 microcontroller.
- *Developing embedded applications* gives the information you need to get started developing your embedded software using the IAR build tools.
- *Data storage* describes how to store data in memory.
- *Functions* gives a brief overview of function-related extensions—mechanisms for controlling functions—and describes some of these mechanisms in more detail.
- *Linking using ILINK* describes the linking process using the IAR ILINK Linker and the related concepts.
- *Linking your application* lists aspects that you must consider when linking your application, including using ILINK options and tailoring the linker configuration file.
- *The DLIB runtime environment* describes the DLIB runtime environment in which an application executes. It covers how you can modify it by setting options, overriding default library modules, or building your own library. The chapter also describes system initialization introducing the file `cstartup.s`, how to use modules for locale, and file I/O.
- *Assembler language interface* contains information required when parts of an application are written in assembler language. This includes the calling convention.
- *Using C* gives an overview of the two supported variants of the C language, and an overview of the compiler extensions, such as extensions to Standard C.
- *Using C++* gives an overview of the level of C++ support.
- *Application-related considerations* discusses a selected range of application issues related to using the compiler and linker.
- *Efficient coding for embedded applications* gives hints about how to write code that compiles to efficient code for an embedded application.

PART 2. REFERENCE INFORMATION

- *External interface details* provides reference information about how the compiler and linker interact with their environment—the invocation syntax, methods for passing options to the compiler and linker, environment variables, the include file search procedure, and the different types of compiler and linker output. The chapter also describes how the diagnostic system works.

- *Compiler options* explains how to set options, gives a summary of the options, and contains detailed reference information for each compiler option.
- *Linker options* gives a summary of the options, and contains detailed reference information for each linker option.
- *Data representation* describes the available data types, pointers, and structure types. This chapter also gives information about type and object attributes.
- *Extended keywords* gives reference information about each of the RH850-specific keywords that are extensions to the standard C/C++ language.
- *Pragma directives* gives reference information about the pragma directives.
- *Intrinsic functions* gives reference information about functions to use for accessing RH850-specific low-level features.
- *The preprocessor* gives a brief overview of the preprocessor, including reference information about the different preprocessor directives, symbols, and other related information.
- *C/C++ standard library functions* gives an introduction to the C or C++ library functions, and summarizes the header files.
- *The linker configuration file* describes the purpose of the linker configuration file, and describes its contents.
- *Section reference* gives reference information about the use of sections.
- *The stack usage control file* describes the syntax and semantics of stack usage control files.
- *IAR utilities* describes the IAR utilities that handle the ELF and DWARF object formats.
- *Implementation-defined behavior for Standard C++* describes how the compiler handles the implementation-defined areas of Standard C++.
- *Implementation-defined behavior for Standard C* describes how the compiler handles the implementation-defined areas of Standard C.
- *Implementation-defined behavior for C89* describes how the compiler handles the implementation-defined areas of the C language standard C89.

Other documentation

User documentation is available as hypertext PDFs and as a context-sensitive online help system in HTML format. You can access the documentation from the Information Center or from the **Help** menu in the IAR Embedded Workbench IDE. The online help system is also available via the F1 key.

USER AND REFERENCE GUIDES

The complete set of IAR Systems development tools is described in a series of guides. Information about:

- System requirements and information about how to install and register the IAR Systems products are available in the *Installation and Licensing Quick Reference Guide* and the *Licensing Guide*.
- Using the IDE for project management and building, is available in the *IDE Project Management and Building Guide for RH850.*
- Using the IAR C-SPY® Debugger, is available in the *C-SPY® Debugging Guide for RH850.*
- Programming for the IAR C/C++ Compiler for RH850 and linking using the IAR ILINK Linker, is available in the *IAR C/C++ Development Guide for RH850.*
- Programming for the IAR Assembler for RH850, is available in the *IAR Assembler Reference Guide for RH850.*
- Performing a static analysis using C-STAT and the required checks, is available in the *C-STAT® Static Analysis Guide*.
- Developing safety-critical applications using the MISRA C guidelines, is available in the *IAR Embedded Workbench® MISRA C:2004 Reference Guide* or the *IAR Embedded Workbench® MISRA C:1998 Reference Guide*.
- Migrating from an older UBROF-based product version to a newer version that uses the ELF/DWARF object format, is available in the guide *IAR Embedded Workbench® Migrating from UBROF to ELF/DWARF*.

Note: Additional documentation might be available depending on your product installation.

THE ONLINE HELP SYSTEM

The context-sensitive online help contains information about:

- IDE project management and building
- Debugging using the IAR C-SPY® Debugger
- The IAR C/C++ Compiler
- The IAR Assembler
- Keyword reference information for the DLIB library functions. To obtain reference information for a function, select the function name in the editor window and press F1.
- C-STAT
- MISRA C

FURTHER READING

These books might be of interest to you when using the IAR Systems development tools:

- Barr, Michael, and Andy Oram, ed. *Programming Embedded Systems in C and C++*. O'Reilly & Associates.
- Harbison, Samuel P. and Guy L. Steele (contributor). *C: A Reference Manual.* Prentice Hall.
- Labrosse, Jean J. *Embedded Systems Building Blocks: Complete and Ready-To-Use Modules in C.* R&D Books.
- Mann, Bernhard. *C für Mikrocontroller.* Franzis-Verlag. [Written in German.]
- Meyers, Scott. *Effective C++.* Addison-Wesley.
- Meyers, Scott. *More Effective C++.* Addison-Wesley.
- Meyers, Scott. *Effective STL.* Addison-Wesley.
- Sutter, Herb. *Exceptional C++: 47 Engineering Puzzles, Programming Problems, and Solutions.* Addison-Wesley.

The web site **isocpp.org** also has a list of recommended books about C++ programming.

WEB SITES

Recommended web sites:

- The Renesas web site, **www.renesas.com**, that contains information and news about the RH850 Family.
- The IAR Systems web site, **www.iar.com**, that holds application notes and other product information.
- The web site of the C standardization working group, **www.open-std.org/jtc1/sc22/wg14**.
- The web site of the C++ Standards Committee, **www.open-std.org/jtc1/sc22/wg21**.
- The C++ programming language web site, **isocpp.org**. This web site also has a list of recommended books about C++ programming.
- The C and C++ reference web site, **en.cppreference.com**.

Document conventions

When, in the IAR Systems documentation, we refer to the programming language C, the text also applies to C++, unless otherwise stated.

When referring to a directory in your product installation, for example `rh850\doc`, the full path to the location is assumed, for example `c:\Program Files\IAR Systems\Embedded Workbench` *`N.n`*`\rh850\doc`, where the initial digit of the version number reflects the initial digit of the version number of the IAR Embedded Workbench shared components.

TYPOGRAPHIC CONVENTIONS

The IAR Systems documentation set uses the following typographic conventions:

Style	Used for
`computer`	• Source code examples and file paths. • Text on the command line. • Binary, hexadecimal, and octal numbers.
`parameter`	A placeholder for an actual value used as a parameter, for example *`filename`*`.h` where *`filename`* represents the name of the file.
[`option`**]**	An optional part of a linker or stack usage control directive, where **[** and **]** are not part of the actual directive, but any `[`, `]`, `{`, or `}` are part of the directive syntax.
{`option`**}**	A mandatory part of a linker or stack usage control directive, where **{** and **}** are not part of the actual directive, but any `[`, `]`, `{`, or `}` are part of the directive syntax.
`[option]`	An optional part of a command line option, pragma directive, or library filename.
`[a|b|c]`	An optional part of a command line option, pragma directive, or library filename with alternatives.
`{a|b|c}`	A mandatory part of a command line option, pragma directive, or library filename with alternatives.
bold	Names of menus, menu commands, buttons, and dialog boxes that appear on the screen.
italic	• A cross-reference within this guide or to another guide. • Emphasis.
…	An ellipsis indicates that the previous item can be repeated an arbitrary number of times.
	Identifies instructions specific to the IAR Embedded Workbench® IDE interface.
	Identifies instructions specific to the command line interface.
	Identifies helpful tips and programming hints.
	Identifies warnings.

Table 1: Typographic conventions used in this guide

NAMING CONVENTIONS

The following naming conventions are used for the products and tools from IAR Systems®, when referred to in the documentation:

Brand name	Generic term
IAR Embedded Workbench® for RH850	IAR Embedded Workbench®
IAR Embedded Workbench® IDE for RH850	the IDE
IAR C-SPY® Debugger for RH850	C-SPY, the debugger
IAR C-SPY® Simulator	the simulator
IAR C/C++ Compiler™ for RH850	the compiler
IAR Assembler™ for RH850	the assembler
IAR ILINK Linker™	ILINK, the linker
IAR DLIB Runtime Environment™	the DLIB runtime environment

Table 2: Naming conventions used in this guide

Part 1. Using the build tools

This part of the *IAR C/C++ Development Guide for RH850* includes these chapters:

- Introduction to the IAR build tools
- Developing embedded applications
- Data storage
- Functions
- Linking using ILINK
- Linking your application
- The DLIB runtime environment
- Assembler language interface
- Using C
- Using C++
- Application-related considerations
- Efficient coding for embedded applications

Introduction to the IAR build tools

- The IAR build tools—an overview
- IAR language overview
- Device support
- Special support for embedded systems

The IAR build tools—an overview

In the IAR product installation you can find a set of tools, code examples, and user documentation, all suitable for developing software for RH850-based embedded applications. The tools allow you to develop your application in C, C++, or in assembler language.

IAR Embedded Workbench® is a powerful Integrated Development Environment (IDE) that allows you to develop and manage complete embedded application projects. It provides an easy-to-learn and highly efficient development environment with maximum code inheritance capabilities, and comprehensive and specific target support. IAR Embedded Workbench promotes a useful working methodology, and therefore a significant reduction in development time.

For information about the IDE, see the *IDE Project Management and Building Guide for RH850*.

The compiler, assembler, and linker can also be run from a command line environment, if you want to use them as external tools in an already established project environment.

THE IAR C/C++ COMPILER

The IAR C/C++ Compiler for RH850 is a state-of-the-art compiler that offers the standard features of the C and C++ languages, plus extensions designed to take advantage of the RH850-specific facilities.

THE IAR ASSEMBLER

The IAR Assembler for RH850 is a powerful relocating macro assembler with a versatile set of directives and expression operators. The assembler features a built-in C language preprocessor, and supports conditional assembly.

The IAR Assembler for RH850 uses the same mnemonics and operand syntax as the Renesas RH850 Assembler, which simplifies the migration of existing code. For more information, see the *IAR Assembler Reference Guide for RH850*.

THE IAR ILINK LINKER

The IAR ILINK Linker for RH850 is a powerful, flexible software tool for use in the development of embedded controller applications. It is equally well suited for linking small, single-file, absolute assembler programs as it is for linking large, relocatable input, multi-module, C/C++, or mixed C/C++ and assembler programs.

SPECIFIC ELF TOOLS

ILINK both uses and produces industry-standard ELF and DWARF as object format, additional IAR utilities that handle these formats are provided:

- The IAR Archive Tool—`iarchive`—creates and manipulates a library (archive) of several ELF object files
- The IAR ELF Tool—`ielftool`—performs various transformations on an ELF executable image (such as, fill, checksum, format conversion etc)
- The IAR ELF Dumper for RH850—`ielfdumprh850`—creates a text representation of the contents of an ELF relocatable or executable image
- The IAR ELF Object Tool—`iobjmanip`—is used for performing low-level manipulation of ELF object files
- The IAR Absolute Symbol Exporter—`isymexport`—exports absolute symbols from a ROM image file, so that they can be used when linking an add-on application.

EXTERNAL TOOLS

For information about how to extend the tool chain in the IDE, see the *IDE Project Management and Building Guide for RH850*.

IAR language overview

The IAR C/C++ Compiler for RH850 supports:

- C, the most widely used high-level programming language in the embedded systems industry. You can build freestanding applications that follow these standards:
  - Standard C—also known as C18. Hereafter, this standard is referred to as *Standard C* in this guide.
  - C89—also known as C94, C90, and ANSI C. This standard is required when MISRA C is enabled in the compiler.
- Standard C++—also known as C++14. A well-established object-oriented programming language with a full-featured library well suited for modular programming. The IAR implementation of Standard C++ does not support exceptions and runtime type information (RTTI).

Each of the supported languages can be used in *strict* or *relaxed* mode, or relaxed with IAR extensions enabled. The strict mode adheres to the standard, whereas the relaxed mode allows some common deviations from the standard. Both the strict and the relaxed mode might contain support for features in future versions of the C/C++ standards.

For more information about C, see the chapter *Using C*.

For more information about C++, see the chapter *Using C++*.

For information about how the compiler handles the implementation-defined areas of the languages, see the chapter *Implementation-defined behavior for Standard C*.

It is also possible to implement parts of the application, or the whole application, in assembler language. See the *IAR Assembler Reference Guide for RH850*.

Device support

To get a smooth start with your product development, the IAR product installation comes with a wide range of device-specific support.

SUPPORTED RH850 DEVICES

The IAR C/C++ Compiler for RH850 supports all devices based on the standard Renesas RH850 microcontroller cores. The following extension is also supported:

- Floating-point unit (FPU) with single or double precision.

PRECONFIGURED SUPPORT FILES

The IAR product installation contains preconfigured files for supporting different devices. If you need additional files for device support, they can be created using one of the provided ones as a template.

Header files for I/O

Standard peripheral units are defined in device-specific I/O header files with the filename extension `h`. The product package supplies I/O files for all devices that are available at the time of the product release. You can find these files, named `io`*`device_name`*`.h`, in the `rh850\inc` directory. Make sure to include the appropriate include file in your application source files. If you need additional I/O header files, they can be created using one of the provided ones as a template.

Linker configuration files

The `rh850\config` directory contains ready-made linker configuration files for all supported devices. The files have the filename extension `icf` and contain the information required by the linker. For more information about the linker configuration file, see *Placing code and data—the linker configuration file*, page 93, and for reference information, the chapter *The linker configuration file*.

Device description files

The debugger handles several of the device-specific requirements, such as definitions of available memory areas, peripheral registers and groups of these, by using device description files. These files are located in the `rh850\config` directory and they have the filename extension `ddf`. The peripheral registers and groups of these can be defined in separate files (filename extension `sfr`), which in that case are included in the `ddf` file. For more information about these files, see the *C-SPY® Debugging Guide for RH850*.

EXAMPLES FOR GETTING STARTED

Example applications are provided with IAR Embedded Workbench. You can use these examples to get started using the development tools from IAR Systems. You can also use the examples as a starting point for your application project.

You can find the examples in the `rh850\examples` directory. The examples are ready to be used as is. They are supplied with ready-made workspace files, together with source code files and all other related files. For information about how to run an example project, see the *IDE Project Management and Building Guide for RH850*.

Special support for embedded systems

This section briefly describes the extensions provided by the compiler to support specific features of the RH850 microcontroller.

EXTENDED KEYWORDS

The compiler provides a set of keywords that can be used for configuring how the code is generated. For example, there are keywords for controlling how to access and store data objects, as well as for controlling how a function should work internally and how it should be called/returned.

By default, language extensions are enabled in the IDE.

The command line option `-e` makes the extended keywords available, and reserves them so that they cannot be used as variable names. See *-e*, page 267 for additional information.

For more information, see the chapter *Extended keywords*. See also *Data storage* and *Functions*.

PRAGMA DIRECTIVES

The pragma directives control the behavior of the compiler, for example how it allocates memory, whether it allows extended keywords, and whether it issues warning messages.

The pragma directives are always enabled in the compiler. They are consistent with standard C, and are useful when you want to make sure that the source code is portable.

For more information about the pragma directives, see the chapter *Pragma directives*.

PREDEFINED SYMBOLS

With the predefined preprocessor symbols, you can inspect your compile-time environment, for example time of compilation or the build number of the compiler.

For more information about the predefined symbols, see the chapter *The preprocessor*.

ACCESSING LOW-LEVEL FEATURES

For hardware-related parts of your application, accessing low-level features is essential. The compiler supports several ways of doing this: intrinsic functions, mixing C and assembler modules, and inline assembler. For information about the different methods, see *Mixing C and assembler*, page 161.

Developing embedded applications

- Developing embedded software using IAR build tools
- The build process—an overview
- Application execution—an overview
- Building applications—an overview
- Basic project configuration

Developing embedded software using IAR build tools

Typically, embedded software written for a dedicated microcontroller is designed as an endless loop waiting for some external events to happen. The software is located in ROM and executes on reset. You must consider several hardware and software factors when you write this kind of software. To assist you, compiler options, extended keywords, pragma directives, etc., are included.

CPU FEATURES AND CONSTRAINTS

The compiler supports FPU operations and `EP`-relative short addressing modes (along with various other addressing modes). Trap functions (`__trap` and `__fetrap`) and call table functions (`__callt` and `__syscall`) are handled automatically without explicit vector numbers.

The compiler supports this by means of compiler options, extended keywords, pragma directives, etc.

MAPPING OF MEMORY

Embedded systems typically contain various types of memory, such as on-chip RAM, external DRAM or SRAM, ROM, EEPROM, or flash memory.

As an embedded software developer, you must understand the features of the different types of memory. For example, on-chip RAM is often faster than other types of memories, and variables that are accessed often would in time-critical applications benefit from being placed here. Conversely, some configuration data might be seldom accessed but must maintain its value after power off, so it should be saved in EEPROM or flash memory.

For efficient memory usage, the compiler provides several mechanisms for controlling placement of functions and data objects in memory. For more information, see *Controlling data and function placement in memory*, page 224.

The linker places sections of code and data in memory according to the directives you specify in the linker configuration file, see *Placing code and data—the linker configuration file*, page 93.

COMMUNICATION WITH PERIPHERAL UNITS

If external devices are connected to the microcontroller, you might need to initialize and control the signaling interface, for example by using chip select pins, and detect and handle external interrupt signals. Typically, this must be initialized and controlled at runtime. The normal way to do this is to use special function registers (SFR). These are typically available at dedicated addresses, containing bits that control the chip configuration.

Standard peripheral units are defined in device-specific I/O header files with the filename extension `h`. See *Device support*, page 49. For an example, see *Accessing special function registers*, page 236.

EVENT HANDLING

In embedded systems, using *interrupts* is a method for handling external events immediately, for example, detecting that a button was pressed. In general, when an interrupt occurs in the code, the microcontroller immediately stops executing the code it runs, and starts executing an interrupt routine instead.

The compiler provides various primitives for managing hardware and software interrupts, which means that you can write your interrupt routines in C, see *Primitives for interrupts, concurrency, and OS-related programming*, page 77.

SYSTEM STARTUP

In all embedded systems, system startup code is executed to initialize the system—both the hardware and the software system—before the `main` function of the application is called.

As an embedded software developer, you must ensure that the startup code is located at the dedicated memory addresses, or can be accessed using a pointer from the vector table. This means that startup code and the initial vector table must be placed in non-volatile memory, such as ROM, EPROM, or flash.

A C/C++ application further needs to initialize all global variables. This initialization is handled by the linker in conjunction with the system startup code. For more information, see *Application execution—an overview*, page 58.

REAL-TIME OPERATING SYSTEMS

In many cases, the embedded application is the only software running in the system. However, using an RTOS has some advantages.

For example, the timing of high-priority tasks is not affected by other parts of the program which are executed in lower priority tasks. This typically makes a program more deterministic and can reduce power consumption by using the CPU efficiently and putting the CPU in a lower-power state when idle.

Using an RTOS can make your program easier to read and maintain, and in many cases smaller as well. Application code can be cleanly separated into tasks that are independent of each other. This makes teamwork easier, as the development work can be easily split into separate tasks which are handled by one developer or a group of developers.

Finally, using an RTOS reduces the hardware dependence and creates a clean interface to the application, making it easier to port the program to different target hardware.

See also *Managing a multithreaded environment*, page 158.

INTEROPERABILITY WITH OTHER BUILD TOOLS

The IAR compiler and linker provide support for the Renesas ABI (Application Binary Interface). For more information about this interface specification, see the **www.renesas.com** web site.

The Renesas ABI specifies full compatibility for C object code. The Renesas ABI does not include specifications for the C/C++ libraries.

The build process—an overview

This section gives an overview of the build process—how the various build tools (compiler, assembler, and linker) fit together, going from source code to an executable image.

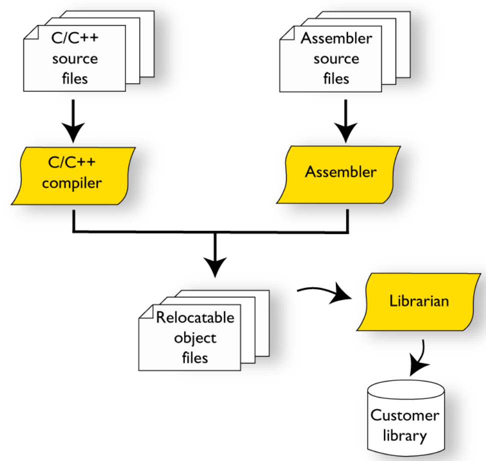
To become familiar with the process in practice, you should go through the tutorials available from the IAR Information Center.

THE TRANSLATION PROCESS

There are two tools in the IDE that translate application source files to intermediary object files—the IAR C/C++ Compiler and the IAR Assembler. Both produce relocatable object files in the industry-standard format ELF, including the DWARF format for debug information.

Note: The compiler can also be used for translating C source code into assembler source code. If required, you can modify the assembler source code which can then be assembled into object code. For more information about the IAR Assembler, see the *IAR Assembler Reference Guide for RH850.*

This illustration shows the translation process:



After the translation, you can choose to pack any number of modules into an archive, or in other words, a library. The important reason you should use libraries is that each module in a library is conditionally linked in the application, or in other words, is only included in the application if the module is used directly or indirectly by a module supplied as an object file. Optionally, you can create a library, then use the IAR utility `iarchive`.

THE LINKING PROCESS

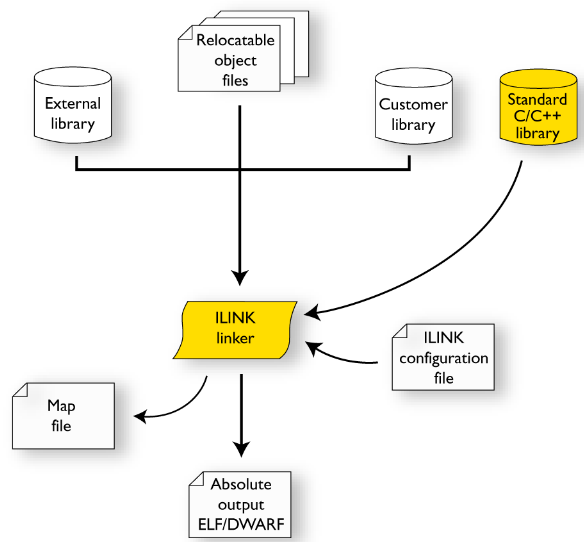
The relocatable modules in object files and libraries, produced by the IAR compiler and assembler cannot be executed as is. To become an executable application, they must be *linked*.

Note: Modules produced by a toolset from another vendor can be included in the build as well. Be aware that this might also require a compiler utility library from the same vendor.

The IAR ILINK Linker (`ilinkrh850.exe`) is used for building the final application. Normally, the linker requires the following information as input:

- Several object files and possibly certain libraries
- A program start label (set by default)
- The linker configuration file that describes placement of code and data in the memory of the target system

This illustration shows the linking process:



Note: The Standard C/C++ library contains support routines for the compiler, and the implementation of the C/C++ standard library functions.

While linking, the linker might produce error messages and logging messages on `stdout` and `stderr`. The log messages are useful for understanding why an application was linked the way it was, for example, why a module was included or a section removed.

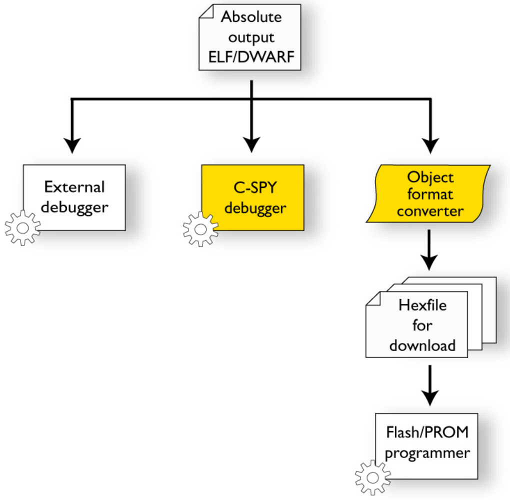
For more information about the procedure performed by the linker, see *The linking process in detail*, page 91.

AFTER LINKING

The IAR ILINK Linker produces an absolute object file in ELF format that contains the executable image. After linking, the produced absolute executable image can be used for:

- Loading into the IAR C-SPY Debugger or any other compatible external debugger that reads ELF and DWARF.
- Programming to a flash/PROM using a flash/PROM programmer. Before this is possible, the actual bytes in the image must be converted into the standard Motorola 32-bit S-record format or the Intel Hex-32 format. For this, use `ielftool`, see *The IAR ELF Tool—ielftool*, page 486.

This illustration shows the possible uses of the absolute output ELF/DWARF file:



Application execution—an overview

This section gives an overview of the execution of an embedded application divided into three phases, the:

- Initialization phase
- Execution phase
- Termination phase.

THE INITIALIZATION PHASE

Initialization is executed when an application is started (the CPU is reset) but before the `main` function is entered. For simplicity, the initialization phase can be divided into:

- Hardware initialization, which as a minimum, generally initializes the stack pointer.

  The hardware initialization is typically performed in the system startup code `cstartup.s` (or the corresponding file for multicore devices, see *System startup and termination*, page 142), and if required, by an extra low-level routine that you provide. It might include resetting/restarting the rest of the hardware, setting up the CPU, etc, in preparation for the software C/C++ system initialization.
- Software C/C++ system initialization

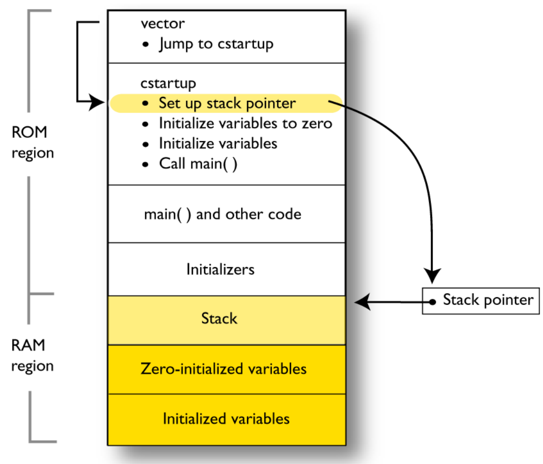
  Typically, this includes assuring that every global (statically linked) C/C++ symbol receives its proper initialization value before the `main` function is called.
- Application initialization

  This depends entirely on your application. It can include setting up an RTOS kernel and starting initial tasks for an RTOS-driven application. For a bare-bone application, it can include setting up various interrupts, initializing communication, initializing devices, etc.

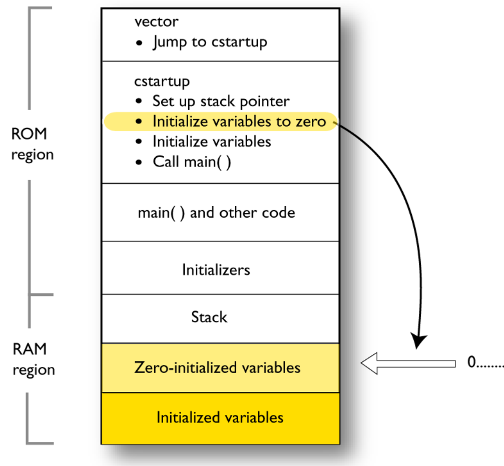
For a ROM/flash-based system, constants and functions are already placed in ROM. The linker has already divided the available RAM into different areas for variables, stack, heap, etc. All symbols placed in RAM must be initialized before the `main` function is called.

The following sequence of illustrations gives a simplified overview of the different stages of the initialization.

- When an application is started, the system startup code first performs hardware initialization, such as initialization of the stack pointer to point at the predefined stack area:

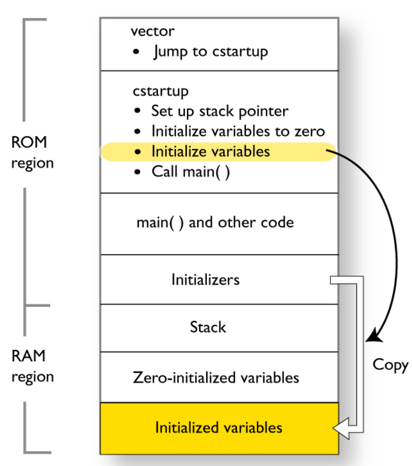


2 Then, memories that should be zero-initialized are cleared, in other words, filled with zeros:



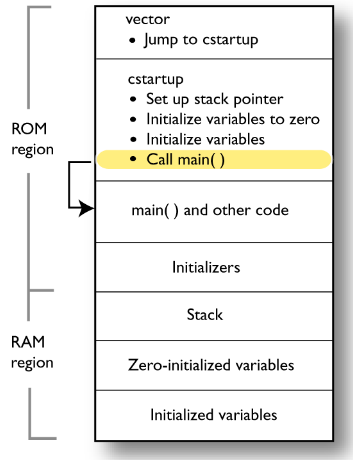
Typically, this is data referred to as *zero-initialized data*—variables declared as, for example, `int i = 0;`

3 For *initialized data*, data declared, for example, like `int i = 6;` the initializers are copied from ROM to RAM



Then, dynamically initialized static objects are constructed, such as C++ objects.

4 Finally, the `main` function is called:



For more information about each stage, see *System startup and termination*, page 142. For more information about data initialization, see *Initialization at system startup*, page 96.

THE EXECUTION PHASE

The software of an embedded application is typically implemented as a loop, which is either interrupt-driven, or uses polling for controlling external interaction or internal events. For an interrupt-driven system, the interrupts are typically initialized at the beginning of the `main` function.

In a system with real-time behavior and where responsiveness is critical, a multi-task system might be required. This means that your application software should be complemented with a real-time operating system (RTOS). In this case, the RTOS and the different tasks must also be initialized at the beginning of the `main` function.

THE TERMINATION PHASE

Typically, the execution of an embedded application should never end. If it does, you must define a proper end behavior.

To terminate an application in a controlled way, either call one of the Standard C library functions `exit`, `_Exit`, `quick_exit`, or `abort`, or return from `main`. If you return from main, the exit function is executed, which means that C++ destructors for static and global variables are called (C++ only) and all open files are closed.

Of course, in case of incorrect program logic, the application might terminate in an uncontrolled and abnormal way—a system crash.

For more information about this, see *System termination*, page 145.

Building applications—an overview

In the command line interface, the following line compiles the source file myfile.c into the object file myfile.o using the default settings:

```
iccrh850 myfile.c
```

You must also specify some critical options, see *Basic project configuration*, page 64.

On the command line, the following line can be used for starting the linker:

```
ilinkrh850 myfile.o myfile2.o -o a.out --config my_configfile.icf
```

In this example, myfile.o and myfile2.o are object files, and my_configfile.icf is the linker configuration file. The option -o specifies the name of the output file.

The application will start executing at a start label. In the IDE, the default start label depends on the device you are developing for:

Type of RH850 device	Default start label
G3 Single-core	__iar_program_start
G3 Multi-core	__iar_program_start*n*
G3 with a PCU core	__iar_program_start*n*_pcu
G4 Single-core	__iar_program_start_g4
G4 Multi-core	__iar_program_start*n*_g4

Table 3: The default start label

n corresponds to the number of cores that your microcontroller has. On the command line, the default label is always __iar_program_start. If your application does not use all microcontroller cores, you must set the start label explicitly in IDE or on the command line.

To change the start point of the application to another label, use the ILINK option --entry, see *--entry*, page 306.

When building a project, the IAR Embedded Workbench IDE can produce extensive build information in the **Build** messages window. This information can be useful, for example, as a base for producing batch files for building on the command line. You can copy the information and paste it in a text file. To activate extensive build information, right-click in the **Build** messages window, and select **All** on the context menu.

Basic project configuration

This section gives an overview of the basic settings needed to generate the best code for the RH850 device you are using. You can specify the options either from the command line interface or in the IDE. On the command line, you must specify each option separately, but if you use the IDE, many options will be set automatically, based on your settings of some of the fundamental options.

You need to make settings for:

- Core
- Data model
- Alignment
- Floating-point unit
- Optimization settings
- Runtime environment, see *Setting up the runtime environment*, page 127
- Customizing the ILINK configuration, see the chapter *Linking your application*.

In addition to these settings, you can use many other options and settings to fine-tune the result even further. For information about how to set options and for a list of all available options, see the chapters *Compiler options*, *Linker options*, and the *IDE Project Management and Building Guide for RH850*, respectively.

PROCESSOR CORE

To make the compiler generate optimum code, you should configure it for the RH850 microcontroller you are using.

Use the `--core` option to select the core for which the code will be generated.

In the IDE, choose **Project>Options>General Options>Target** and choose an appropriate device from the **Device** drop-down list. The core option will then be automatically selected.

Note: Device-specific configuration files for the linker and the debugger will also be automatically selected.

DATA MODEL

One of the characteristics of the RH850 microcontroller is a trade-off in how memory is accessed, ranging from cheap access to small memory areas, up to more expensive access methods that can access any location.

In the compiler, you can set a default memory access method by selecting a data model. These data models are supported:

- The *Tiny* data model uses near memory for storing data
- The *Small* data model uses brel memory for storing data
- The *Medium* data model uses brel23 memory for storing data
- The *Large* data model uses huge memory for storing data.

All the data models are available with or without support for *short addressing*. The chapter *Data storage* covers data models in greater detail and how to override the default access method for individual variables.

OPTIMIZATION FOR SPEED AND SIZE

The compiler's optimizer performs, among other things, dead-code elimination, constant propagation, inlining, common sub-expression elimination, and precision reduction. It also performs loop optimizations, such as unrolling and induction variable elimination.

You can choose between several optimization levels, and for the highest level you can choose between different optimization goals—*size*, *speed*, or *balanced*. Most optimizations will make the application both smaller and faster. However, when this is not the case, the compiler uses the selected optimization goal to decide how to perform the optimization.

The optimization level and goal can be specified for the entire application, for individual files, and for individual functions. In addition, some individual optimizations, such as function inlining, can be disabled.

For information about compiler optimizations and for more information about efficient coding techniques, see the chapter *Efficient coding for embedded applications*.

Data storage

- Introduction
- Memory types
- Data models
- Storage of auto variables and parameters
- Dynamic memory on the heap

Introduction

The RH850 Family cores have one continuous 4 Gbytes memory space. Different types of physical memory can be placed in the memory range. A typical application will have both read-only memory (ROM) and read/write memory (RAM). In addition, some parts of the memory range contain processor control registers and peripheral units.

The compiler can access memory in different ways. The access methods range from generic but expensive methods that can access the full memory space, to cheap methods that can access limited memory areas. For more information about this, see *Memory types*, page 68.

DIFFERENT WAYS TO STORE DATA

In a typical application, data can be stored in memory in three different ways:

- *Auto variables*

  All variables that are local to a function, except those declared static, are stored either in registers or on the stack. These variables can be used as long as the function executes. When the function returns to its caller, the memory space is no longer valid. For more information, see *Storage of auto variables and parameters*, page 74.

- *Global variables, module-static variables, and local variables declared* `static`

  In this case, the memory is allocated once and for all. The word *static* in this context means that the amount of memory allocated for this kind of variables does not change while the application is running. For more information, see *Data models*, page 73 and *Memory types*, page 68.

- *Dynamically allocated data*

  An application can allocate data on the *heap*, where the data remains valid until it is explicitly released back to the system by the application. This type of memory is useful when the number of objects is not known until the application executes.

  Note: There are potential risks connected with using dynamically allocated data in systems with a limited amount of memory, or systems that are expected to run for a long time. For more information, see *Dynamic memory on the heap*, page 75.

Memory types

This section describes the concept of *memory types* used for accessing data by the compiler. For each memory type, the capabilities and limitations are discussed.

INTRODUCTION TO MEMORY TYPES

The compiler uses different memory types to access data that is placed in different areas of the memory. There are different methods for reaching memory areas, and they have different costs when it comes to code space, execution speed, and register usage. The access methods range from generic but expensive methods that can access the full memory space, to cheap methods that can access limited memory areas. Each memory type corresponds to one memory access method. If you map different memories—or part of memories—to memory types, the compiler can generate code that can access data efficiently.

For example, the memory accessed using the near memory access method is called near memory.

To choose a default memory type that your application will use, select a *data model*. However, it is possible to specify—for individual variables—different memory types. This makes it possible to create an application that can contain a large amount of data, and at the same time make sure that variables that are used often are placed in memory that can be efficiently accessed.

near

The near memory consists of the low and high 32 Kbytes of memory. In hexadecimal notation, this is the addresses `0x00000000-0x00007FFF` and `0xFFFF8000-0xFFFFFFFF`.

This combination of memory ranges might seem odd. The explanation is that the calculation wraps around when an address expression becomes negative. Because the address space on the RH850 microcontroller is 32 bits, the address below 0 can be seen as `0xFFFFFFFF`. Thus an alternative way to see the memory range in the accessible memory is simply ±32 Kbytes around address 0.

Accessing near memory is very efficient, typically only one machine instruction is needed.

brel (base-relative)

Using base-relative addressing, a 64-Kbyte RAM area and a 64-Kbyte ROM area can be accessed. These brel memory areas can be placed individually at any location in memory.

The name *base-relative* comes from the use of processor registers as base pointers to the memory areas. The RAM area is accessed using the register `R4`, also named `GP` (global pointer). The ROM area is accessed using the register `R5`, also known as `TP` (text pointer).

Access to this type of memory is almost as efficient as accessing near memory.

Because different access methods are used for brel RAM and brel ROM, respectively, a variable declaration must specify whether a RAM or ROM access should be used. In C, this is possible for all variables.

Note: In standard C++, a constant variable without constructors can either be placed in ROM if it is initialized with a constant, or in RAM if an expression that must be executed at runtime is used. To solve this ambiguity, the compiler does not allow constant variables without constructors in RAM, only in ROM.

brel23 (base-relative23)

Using the same base pointers as brel memory, the brel23 memory can access an 8-Mbyte RAM area and an 8-Mbyte ROM area.

huge

The RH850 microcontroller has an address space of 4 Gbytes—huge memory. Using this memory type, the data objects can be placed anywhere in memory. Also, unlike the other memory types, there is no limitation on the size of the objects that can be placed in this memory type.

The drawback of the huge memory type is that the code generated to access the memory is larger and also slower than that of any of the other memory types. In addition, the code consumes more processor registers, possibly forcing local variables to be stored on the stack rather than being allocated in registers.

saddr (short addressing)

Short addressing can be used for storing variables in a relatively small memory area, 256 bytes, which can be accessed using highly efficient special instructions.

There are two limitations:

- Objects that can be accessed using byte access can only occupy 128 of these bytes. This, of course, includes the character types but also structure types that contain character types.
- If the variable data contains an unsigned `char` or unsigned `short`, the accessible area is even smaller; only the first 32 bytes can be accessed.

To use saddr memory, it must be enabled; see --*enable_saddr_support*, page 268.

Note: If the saddr memory type is not enabled, the compiler can use the `EP` register and the special instructions for other purposes. For this reason, this feature should only be used when a small number of global or static variables that will be accessed often (if speed is an issue) or exist in many locations (if you need to save code space).

USING DATA MEMORY ATTRIBUTES

The compiler provides a set of *extended keywords*, which can be used as *data memory attributes*. These keywords let you override the default memory type for individual data objects, which means that you can place data objects in other memory areas than the default memory. This also means that you can fine-tune the access method for each individual data object, which results in smaller code size.

This table summarizes the available memory types and their corresponding keywords:

Memory type	Keyword	Address range	Default in data model
Near	`__near`	±32 Kbytes around `0x0`	Tiny
Base-relative	`__brel`	64 Kbytes anywhere in RAM and 64 Kbytes anywhere in ROM	Small
Base-relative23	`__brel23`	8 Mbytes in RAM and 8 Mbytes in ROM.	Medium
Huge	`__huge`	Full memory	Large
Short addressing	`__saddr`	`EP` to `EP` + 255 bytes	—

Table 4: Memory types and their corresponding memory attributes

In this table `EP` is the Element Pointer, an alias for the processor register `R30`. For more details, see *Memory access methods*, page 178.

The keywords are only available if language extensions are enabled in the compiler.

In the IDE, language extensions are enabled by default.

Use the `-e` compiler option to enable language extensions. See *-e*, page 267 for additional information.

For more information about each keyword, see *Descriptions of extended keywords*, page 346.

Syntax for type attributes used on data objects

If you select the *uniform attribute syntax*, data type attributes use the same syntax rules as the type qualifiers `const` and `volatile`.

If not, data type attributes use almost the same syntax rules as the type qualifiers `const` and `volatile`. For example:

```
__brel int i;
int __brel j;
```

Both `i` and `j` are placed in brel memory.

Unlike `const` and `volatile`, when a type attribute is used before the type specifier in a derived type, the type attribute applies to the object, or typedef itself, except in structure member declarations.

```
int * __brel p;        /* pointer in brel memory */

__brel int * p;        /* pointer in brel memory */
```

The third case is interpreted differently when uniform attribute syntax is selected. If so, it is equivalent to the first case, just as would be the case if `const` or `volatile` were used correspondingly.

In all cases, if a memory attribute is not specified, an appropriate default memory type is used, which depends on the data model in use.

Using a type definition can sometimes make the code clearer:

```
typedef __brel int d16_int;
d16_int *q1;
```

`d16_int` is a typedef for integers in brel memory. The variable `q1` can point to such integers.

You can also use the `#pragma type_attributes` directive to specify type attributes for a declaration. The type attributes specified in the pragma directive are applied to the data object or typedef being declared.

```
#pragma type_attribute=__brel
int * q2;
```

The variable `q2` is placed in brel memory.

For more information about the uniform attribute syntax, see --*uniform_attribute_syntax*, page 290 and --*no_uniform_attribute_syntax*, page 281.

Type definitions

Storage can also be specified using type definitions. These two declarations are equivalent:

```
/* Defines via a typedef */
typedef char __near Byte;
typedef Byte *BytePtr;
Byte aByte;
BytePtr aBytePointer;

/* Defines directly */
__near char aByte;
/* No memory attribute necessary for pointers */
char __near *aBytePointer;
```

STRUCTURES AND MEMORY TYPES

For structures, the entire object is placed in the same memory type. It is not possible to place individual structure members in different memory types.

In the example below, the variable `gamma` is a structure placed in brel memory.

```
struct MyStruct
{
  int mAlpha;
  int mBeta;
};

__near struct MyStruct gamma;
```

This declaration is incorrect:

```
struct MyStruct
{
  int mAlpha;
  __near int mBeta; /* Incorrect declaration */
};
```

C++ AND MEMORY TYPES

Instances of C++ classes are placed into a memory (just like all other objects) either implicitly, or explicitly using memory type attributes or other IAR language extensions. Non-static member variables, like structure fields, are part of the larger object and cannot be placed individually into specified memories.

In non-static member functions, the non-static member variables of a C++ object can be referenced via the `this` pointer, explicitly or implicitly. The `this` pointer is of the default data pointer type unless class memory is used, see *Using IAR attributes with classes*, page 196.

Static member variables can be placed individually into a data memory in the same way as free variables.

For more information about C++ classes, see *Using IAR attributes with classes*, page 196.

Data models

Use *data models* to specify in which part of memory the compiler should place static and global variables by default. This means that the data model controls:

- The default memory type
- The default placement of static and global variables, and constant literals
- Dynamically allocated data, for example data allocated with `malloc`, or, in C++, the operator `new`
- The placement of the runtime stack.

The data model only specifies the default memory type. It is possible to override this for individual variables and pointers. For information about how to specify a memory type for individual objects, see *Using data memory attributes*, page 70.

Note: Your choice of data model does not affect the placement of code.

SPECIFYING A DATA MODEL

Four data models are implemented: Tiny, Small, Medium, and Large. The data models are controlled by the `--data_model` option. Each model has a default memory type and a default pointer size. If you do not specify a data model option, the compiler will use the Small data model.

Your project can only use one data model at a time, and the same model must be used by all user modules and all library modules. However, you can override the default memory type for individual data objects by explicitly specifying a memory attribute, see *Using data memory attributes*, page 70.

This table summarizes the different data models:

Data model name	Default memory attribute	Placement of data
Tiny	`__near`	Low 32 Kbytes or high 32 Kbytes

Table 5: Data model characteristics

Data model name	Default memory attribute	Placement of data
Small (default)	`__brel`	64 Kbytes RAM and 64 Kbytes ROM, anywhere in memory
Medium	`__brel23`	8 Mbytes in RAM and 8 Mbytes in ROM.
Large	`__huge`	The entire 4 Gbytes of memory

Table 5: Data model characteristics (Continued)

See the *IDE Project Management and Building Guide for RH850* for information about setting options in the IDE.

Use the `--data_model` option to specify the data model for your project; see *--data_model*, page 261.

Storage of auto variables and parameters

Variables that are defined inside a function—and not declared static—are named auto variables by the C standard. A few of these variables are placed in processor registers, while the rest are placed on the stack. From a semantic point of view, this is equivalent. The main differences are that accessing registers is faster, and that less memory is required compared to when variables are located on the stack.

Auto variables can only live as long as the function executes—when the function returns, the memory allocated on the stack is released.

THE STACK

The stack can contain:

- Local variables and parameters not stored in registers
- Temporary results of expressions
- The return value of a function (unless it is passed in registers)
- Processor state during interrupts
- Processor registers that should be restored before the function returns (callee-save registers).
- Canaries, used in stack-protected functions. See *Stack protection*, page 87.

The stack is a fixed block of memory, divided into two parts. The first part contains allocated memory used by the function that called the current function, and the function that called it, etc. The second part contains free memory that can be allocated. The borderline between the two areas is called the top of stack and is represented by the stack pointer, which is a dedicated processor register. Memory is allocated on the stack by moving the stack pointer.

A function should never refer to the memory in the area of the stack that contains free memory. The reason is that if an interrupt occurs, the called interrupt function can allocate, modify, and—of course—deallocate memory on the stack.

See also *Stack considerations*, page 204 and *Setting up stack memory*, page 112.

Advantages

The main advantage of the stack is that functions in different parts of the program can use the same memory space to store their data. Unlike a heap, a stack will never become fragmented or suffer from memory leaks.

It is possible for a function to call itself either directly or indirectly—a recursive function—and each invocation can store its own data on the stack.

Potential problems

The way the stack works makes it impossible to store data that is supposed to live after the function returns. The following function demonstrates a common programming mistake. It returns a pointer to the variable `x`, a variable that ceases to exist when the function returns.

```
int *MyFunction()
{
  int x;
  /* Do something here. */
  return &x; /* Incorrect */
}
```

Another problem is the risk of running out of stack space. This will happen when one function calls another, which in turn calls a third, etc., and the sum of the stack usage of each function is larger than the size of the stack. The risk is higher if large data objects are stored on the stack, or when recursive functions are used.

Dynamic memory on the heap

Memory for objects allocated on the heap will live until the objects are explicitly released. This type of memory storage is very useful for applications where the amount of data is not known until runtime.

In C, memory is allocated using the standard library function `malloc`, or one of the related functions `calloc` and `realloc`. The memory is released again using `free`.

In C++, a special keyword, `new`, allocates memory and runs constructors. Memory allocated with `new` must be released using the keyword `delete`.

For information about how to set up the size for heap memory, see *Setting up heap memory*, page 112.

POTENTIAL PROBLEMS

Applications that use heap-allocated data objects must be carefully designed, as it is easy to end up in a situation where it is not possible to allocate objects on the heap.

The heap can become exhausted if your application uses too much memory. It can also become full if memory that no longer is in use was not released.

For each allocated memory block, a few bytes of data for administrative purposes is required. For applications that allocate a large number of small blocks, this administrative overhead can be substantial.

There is also the matter of fragmentation; this means a heap where small sections of free memory is separated by memory used by allocated objects. It is not possible to allocate a new object if no piece of free memory is large enough for the object, even though the sum of the sizes of the free memory exceeds the size of the object.

Unfortunately, fragmentation tends to increase as memory is allocated and released. For this reason, applications that are designed to run for a long time should try to avoid using memory allocated on the heap.

Functions

- Function-related extensions
- Primitives for interrupts, concurrency, and OS-related programming
- Inlining functions
- Stack protection

Function-related extensions

In addition to supporting Standard C, the compiler provides several extensions for writing functions in C. Using these, you can:

- Use primitives for interrupts, concurrency, and OS-related programming
- Control function inlining
- Facilitate function optimization
- Access hardware features.

The compiler uses compiler options, extended keywords, pragma directives, and intrinsic functions to support this.

For more information about optimizations, see *Efficient coding for embedded applications*, page 221. For information about the available intrinsic functions for accessing hardware operations, see the chapter *Intrinsic functions*.

Primitives for interrupts, concurrency, and OS-related programming

The IAR C/C++ Compiler for RH850 provides the following primitives related to writing interrupt functions, concurrent functions, and OS-related functions:

- The extended keywords: `__interrupt`, `__task`, `__trap`, `__callt`, `__syscall`, `__fetrap`, `__fast_interrupt`, `__monitor`
- The pragma directive, `#pragma vector`
- The intrinsic functions: `__enable_interrupt`, `__disable_interrupt`, `__get_interrupt_state`, `__set_interrupt_state`.

INTERRUPT FUNCTIONS

In embedded systems, using interrupts is a method for handling external events immediately; for example, detecting that a button was pressed.

Interrupt service routines

In general, when an interrupt occurs in the code, the microcontroller immediately stops executing the code it runs, and starts executing an interrupt routine instead. It is important that the environment of the interrupted function is restored after the interrupt is handled (this includes the values of processor registers and the processor status register). This makes it possible to continue the execution of the original code after the code that handled the interrupt was executed.

The RH850 microcontroller supports many interrupt sources. For each interrupt source, an interrupt routine can be written. Each interrupt routine is associated with a vector number, which is specified in the RH850 microcontroller documentation from the chip manufacturer. If you want to handle several different interrupts using the same interrupt routine, you can specify several interrupt vectors.

Interrupt vectors and the interrupt vector table

For the RH850 microcontroller, the reset vector always starts at the address `0x0`, which is the base for the exception vectors pointed to by the `RBASE` system register. The interrupt vector base is pointed to by the system register `INTBP`.

The exception vector can be moved and is then pointed to by the system register `EBASE`.

By default, the vector table is populated with a *default interrupt handler* which returns immediately. For each interrupt source that has no explicit interrupt service routine, the default interrupt handler will be called. If you write your own service routine for a specific vector, that routine will override the default interrupt handler.

The header file `io`*`device`*`.h`, where *`device`* corresponds to the selected device, contains predefined names for the existing interrupt vectors.

Defining an interrupt function—an example

To define an interrupt function, the `__interrupt` keyword and the `#pragma vector` directive can be used. For example:

```
#pragma vector = 0x13  /* or a symbol defined in I/O header file
                       */
__interrupt void MyInterruptRoutine(void)
{
  /* Do something */
}
```

Note: An interrupt function must have the return type `void`, and it cannot specify any parameters.

Interrupt function return methods

There are two available return methods for exceptions and interrupts: The EI return method and the FE return method. Which registers that the compiler uses for storing the return address of an interrupt handler function depends on the return method and on the exact source of the exception:

- The EI return method is used for normal interrupts, for example peripheral interrupts such as timers or UARTs. These interrupts are on the EI level and use the system registers `EIPC` and `EIPSW` to save the return address and status word contents. They must execute an `EIRET` instruction to restore these resources correctly. To specify that an interrupt should use this return method, use the `__ei_int` keyword.
- The FE return method is used for higher-level exceptions on the FE level. They store their return information in the system registers `FEPC` and `FEPSW`, and return using the `FERET` instruction. To specify that an exception should use this return method, use the `__fe_int` keyword.

When a function is declared only with `__interrupt`, it will by default use the EI return method. To override an FE level exception handler, use the `__fe_int` keyword together with `__interrupt`, like this:

```
__fe_int __interrupt void __syserr_exception_handler(void)
{
  exception_source = 4711;
  abort();
}
```

When you overload an exception handler, look in the file `default_handler.c` where all exception handlers are declared in C.

Interrupt and C++ member functions

Only `static` member functions can be interrupt functions. When a non-static member function is called, it must be applied to an object. When an interrupt occurs and the interrupt function is called, there is no object available to apply the member function to.

TRAP FUNCTIONS

A trap is a kind of exception that can be activated when a specific event occurs or is called. A trap function is called by the `TRAP` assembler instruction and returns just like an interrupt function using the `EIRET` instruction. An fetrap function is called by the `FETRAP` instruction on the `FE` interrupt level and returns using the `FERET` instruction. In many respects, a trap function behaves as a normal function; it can accept parameters, return a value, and it uses the same calling convention as other functions.

The typical use for trap functions is for the client interface of an operating system. If this interface is implemented using trap functions, the operating system part of an application can be updated independently of the rest of the system.

The linker will automatically assign a vector number for the function. Vector numbers can be made explicit, but you cannot use both automatic and explicit vector number assignment in the same project.

The keywords `__trap` and `__fetrap` can be used to define trap functions. For example, this piece of code defines a function doubling its argument:

```
__trap int Twice(int x)
{
  return x + x;
}
```

When a trap function is used, the compiler ensures that the application also will include the appropriate trap-handling code. See the chapter *Assembler language interface* for more information.

By default, trap functions are handled by included exception handlers defined in the file `exception_vector.s`. To override these default handlers with your own handlers, you must change the definitions in this file. (Remember to make a backup copy of the file first.)

Trap and C++ member functions

Virtual member functions cannot be trap functions.

CALL TABLE FUNCTIONS

The call table instructions—`CALLT` and `SYSCALL`—can be used to call a fixed set of functions.

The linker will automatically assign a vector for each function. You cannot mix automatic vectors and vectors declared explicitly using the `#pragma vector` directive in the same project.

Callt functions

The number of callt functions is limited to 64. This type of function is intended to be used in roughly the same situations as trap functions.

The advantage over `TRAP` functions is that a system can contain 64 callt functions, whereas only 32 trap functions can be defined. It is also more efficient to call a callt function.

Each callt function must be associated with a vector ranging from 0 to 63. The `__callt` keyword and the `#pragma vector` directive can be used to define callt functions. This example defines a function that doubles its argument:

```
#pragma vector=15
__callt int twice(int x)
{
  return x + x;
}
```

Syscall functions

The number of syscall functions is limited to 256. This type of function is intended to be used in roughly the same situations as trap functions.

The advantage over `TRAP` functions is that a system can contain 256 syscall functions, whereas only 32 trap functions can be defined. It is also more efficient to call a syscall function.

This instruction is dedicated to calling the system service of an operating system.

Each syscall function must be associated with a vector ranging from 0 to 255. The `__syscall` keyword and the `#pragma vector` directive can be used to define syscall functions. This example defines a function that doubles its argument:

```
#pragma vector=15
__syscall int twice(int x)
{
  return x + x;
}
```

MONITOR FUNCTIONS

A monitor function causes interrupts to be disabled during execution of the function. At function entry, the status register is saved and interrupts are disabled. At function exit, the original status register is restored, and thereby the interrupt status that existed before the function call is also restored.

To define a monitor function, you can use the `__monitor` keyword. For more information, see *__monitor*, page 349.

Avoid using the `__monitor` keyword on large functions, since the interrupt will otherwise be turned off for too long.

Example of implementing a semaphore in C

In the following example, a binary semaphore—that is, a mutex—is implemented using one static variable and two monitor functions. A monitor function works like a critical region, that is no interrupt can occur and the process itself cannot be swapped out. A semaphore can be locked by one process, and is used for preventing processes from simultaneously using resources that can only be used by one process at a time, for example a USART. The `__monitor` keyword assures that the lock operation is atomic; in other words it cannot be interrupted.

```
/* This is the lock-variable. When non-zero, someone owns it. */
static volatile unsigned int sTheLock = 0;

/* Function to test whether the lock is open, and if so take it.
 * Returns 1 on success and 0 on failure.
 */

__monitor int TryGetLock(void)
{
  if (sTheLock == 0)
  {
    /* Success, nobody has the lock. */

    sTheLock = 1;
    return 1;
  }
  else
  {
    /* Failure, someone else has the lock. */

    return 0;
  }
}

/* Function to unlock the lock.
 * It is only callable by one that has the lock.
 */

__monitor void ReleaseLock(void)
{
  sTheLock = 0;
}
```

```
/* Function to take the lock. It will wait until it gets it. */

void GetLock(void)
{
  while (!TryGetLock())
  {
    /* Normally, a sleep instruction is used here. */
  }
}

/* An example of using the semaphore. */

void MyProgram(void)
{
  GetLock();

  /* Do something here. */

  ReleaseLock();
}
```

Example of implementing a semaphore in C++

In C++, it is common to implement small methods with the intention that they should be inlined. However, the compiler does not support inlining of functions and methods that are declared using the `__monitor` keyword.

In the following example in C++, an auto object is used for controlling the monitor block, which uses intrinsic functions instead of the `__monitor` keyword.

```
#include <intrinsics.h>

/* Class for controlling critical blocks. */
class Mutex
{
public:
  Mutex()
  {
    // Get hold of current interrupt state.
    mState = __get_interrupt_state();

    // Disable all interrupts.
    __disable_interrupt();
  }

  ~Mutex()
  {
    // Restore the interrupt state.
    __set_interrupt_state(mState);
  }
```

```
private:
  __istate_t mState;
};

class Tick
{
public:
  // Function to read the tick count safely.
  static long GetTick()
  {
    long t;

    // Enter a critical block.
    {
      Mutex m;

      // Get the tick count safely,
      t = smTickCount;
    }
    // and return it.
    return t;
  }

private:
  static volatile long smTickCount;
};

volatile long Tick::smTickCount = 0;

extern void DoStuff();

void MyMain()
{
  static long nextStop = 100;

  if (Tick::GetTick() >= nextStop)
  {
    nextStop += 100;
    DoStuff();
  }
}
```

Inlining functions

Function inlining means that a function, whose definition is known at compile time, is integrated into the body of its caller to eliminate the overhead of the function call. This optimization, which is performed at optimization level High, normally reduces execution time, but might increase the code size. The resulting code might become more difficult to debug. Whether the inlining actually occurs is subject to the compiler's heuristics.

The compiler heuristically decides which functions to inline. Different heuristics are used when optimizing for speed, size, or when balancing between size and speed. Normally, code size does not increase when optimizing for size.

C VERSUS C++ SEMANTICS

In C++, all definitions of a specific inline function in separate translation units must be exactly the same. If the function is not inlined in one or more of the translation units, then one of the definitions from these translation units will be used as the function implementation.

In C, you must manually select one translation unit that includes the non-inlined version of an inline function. You do this by explicitly declaring the function as `extern` in that translation unit. If you declare the function as `extern` in more than one translation unit, the linker will issue a *multiple definition* error. In addition, in C, inline functions cannot refer to static variables or functions.

For example:

```
// In a header file.
static int sX;
inline void F(void)
{
  //static int sY; // Cannot refer to statics.
  //sX;            // Cannot refer to statics.
}

// In one source file.
// Declare this F as the non-inlined version to use.
extern inline void F();
```

FEATURES CONTROLLING FUNCTION INLINING

There are several mechanisms for controlling function inlining:

- The `inline` keyword advises the compiler that the function defined immediately after the directive should be inlined.

  If you compile your function in C or C++ mode, the keyword will be interpreted according to its definition in Standard C or Standard C++, respectively.

  The main difference in semantics is that in Standard C you cannot (in general) simply supply an inline definition in a header file. You must supply an external definition in one of the compilation units, by designating the inline definition as being external in that compilation unit.

- `#pragma inline` is similar to the `inline` keyword, but with the difference that the compiler always uses C++ inline semantics.

  By using the `#pragma inline` directive you can also disable the compiler's heuristics to either force inlining or completely disable inlining. For more information, see *inline*, page 371.
- `--use_c++_inline` forces the compiler to use C++ semantics when compiling a Standard C source code file.
- `--no_inline`, `#pragma optimize=no_inline`, and `#pragma inline=never` all disable function inlining. By default, function inlining is enabled at optimization level High.

The compiler can only inline a function if the definition is known. Normally, this is restricted to the current translation unit. However, when the `--mfc` compiler option for multi-file compilation is used, the compiler can inline definitions from all translation units in the multi-file compilation unit. For more information, see *Multi-file compilation units*, page 228.

For more information about function inlining optimization, see *Function inlining*, page 231.

Stack protection

In software, a stack buffer overflow occurs when a program writes to a memory address on the program's call stack outside of the intended data structure, which is usually a fixed-length buffer. The result is, almost always, corruption of nearby data, and it can even change which function to return to. If it is deliberate, it is often called stack smashing. One method to guard against stack buffer overflow is to use stack canaries, named for their analogy to the use of canaries in coal mines.

STACK PROTECTION IN THE IAR C/C++ COMPILER

The IAR C/C++ Compiler for RH850 supports stack protection.

To enable stack protection for functions considered needing it, use the compiler option `--stack_protection`. For more information, see *--stack_protection*, page 289.

The IAR Systems implementation of stack protection uses a heuristic to determine whether a function needs stack protection or not. If any defined local variable has the array type or a structure type that contains a member of array type, the function will need stack protection. In addition, if the address of any local variable is propagated outside of a function, such a function will also need stack protection.

If a function needs stack protection, the local variables are sorted to let the variables with array type to be placed as high as possible in the function stack block. After those variables, a canary element is placed. The canary is initialized at function entrance. The initialization value is taken from the global variable `__stack_chk_guard`. At function exit, the code verifies that the canary element still contains the original value. If not, the function `__stack_chk_fail` is called.

USING STACK PROTECTION IN YOUR APPLICATION

To use stack protection, you must define these objects in your application:

- `extern uint32_t __stack_chk_guard`

  The global variable `__stack_chk_guard` must be initialized prior to first use. If the initialization value is randomized, it will be more secure.

- `__nounwind __noreturn void __stack_chk_fail(void)`

  The purpose of the function `__stack_chk_fail` is to notify about the problem and then terminate the application.

  Note: The return address from this function will point into the function that failed.

The file `stack_protection.c` in the directory `rh850\src\lib\runtime` can be used as a template for both `__stack_chk_guard` and `__stack_chk_fail`.

Linking using ILINK

- Linking—an overview
- Modules and sections
- The linking process in detail
- Placing code and data—the linker configuration file
- Initialization at system startup
- Stack usage analysis

Linking—an overview

The IAR ILINK Linker is a powerful, flexible software tool for use in the development of embedded applications. It is equally well suited for linking small, single-file, absolute assembler programs as it is for linking large, relocatable, multi-module, C/C++, or mixed C/C++ and assembler programs.

The linker combines one or more relocatable object files—produced by the IAR Systems compiler or assembler—with selected parts of one or more object libraries to produce an executable image in the industry-standard format *Executable and Linking Format* (ELF).

The linker will automatically load only those library modules—user libraries and Standard C or C++ library variants—that are actually needed by the application you are linking. Furthermore, the linker eliminates duplicate sections and sections that are not required.

The linker uses a *configuration file* where you can specify separate locations for code and data areas of your target system memory map. This file also supports automatic handling of the application's initialization phase, which means initializing global variable areas and code areas by copying initializers and possibly decompressing them as well.

The final output produced by ILINK is an absolute object file containing the executable image in the ELF (including DWARF for debug information) format. The file can be downloaded to C-SPY or any other compatible debugger that supports ELF/DWARF, or it can be stored in EPROM or flash.

To handle ELF files, various tools are included. For information about included utilities, see *Specific ELF tools*, page 48.

Modules and sections

Each relocatable object file contains one module, which consists of:

- Several sections of code or data
- Runtime attributes specifying various types of information, for example, the version of the runtime environment
- Optionally, debug information in DWARF format
- A symbol table of all global symbols and all external symbols used.

A *section* is a logical entity containing a piece of data or code that should be placed at a physical location in memory. A section can consist of several *section fragments*, typically one for each variable or function (symbols). A section can be placed either in RAM or in ROM. In a normal embedded application, sections that are placed in RAM do not have any content, they only occupy space.

Each section has a name and a type attribute that determines the content. The type attribute is used (together with the name) for selecting sections for the ILINK configuration.

The main purpose of section attributes is to distinguish between sections that can be placed in ROM and sections that must be placed in RAM:

`ro|readonly`	ROM sections
`rw|readwrite`	RAM sections

In each category, sections can be further divided into those that contain code and those that contain data, resulting in four main categories:

`ro code`	Normal code
`ro data`	Constants
`rw code`	Code copied to RAM
`rw data`	Variables

`readwrite data` also has a subcategory—`zi|zeroinit`—for sections that are zero-initialized at application startup.

Note: In addition to these section types—sections that contain the code and data that are part of your application—a final object file will contain many other types of sections, for example, sections that contain debugging information or other type of meta information.

A section is the smallest linkable unit—but if possible, ILINK can exclude smaller units—section fragments—from the final application. For more information, see *Keeping modules*, page 111, and *Keeping symbols and sections*, page 111.

At compile time, data and functions are placed in different sections. At link time, one of the most important functions of the linker is to assign addresses to the various sections used by the application.

The IAR build tools have many predefined section names. For more information about each section, see the chapter *Section reference*.

You can group sections together for placement by using blocks. See *define block directive*, page 433.

The linking process in detail

The relocatable modules in object files and libraries, produced by the IAR compiler and assembler, cannot be executed as is. To become an executable application, they must be *linked*.

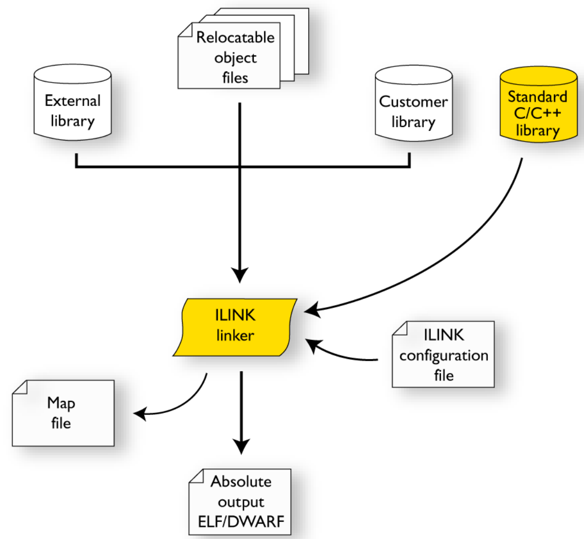
Note: Modules produced by a toolset from another vendor can be included in the build as well, as long as the module is Renesas ABI (Renesas Application Binary Interface) compliant. Be aware that this might also require a compiler utility library from the same vendor.

The linker is used for the link process. It normally performs the following procedure (note that some of the steps can be turned off by command line options or by directives in the linker configuration file):

- Determine which modules to include in the application. Modules provided in object files are always included. A module in a library file is only included if it provides a definition for a global symbol that is referenced from an included module.
- Select which standard library files to use. The selection is based on attributes of the included modules. These libraries are then used for satisfying any still outstanding undefined symbols.
- Handle symbols with more than one definition. If there is more than one non-weak definition, an error is emitted. Otherwise, one of the definitions is picked (the non-weak one, if there is one) and the others are suppressed. Weak definitions are typically used for inline and template functions. If you need to override some of the non-weak definitions from a library module, you must ensure that the library module is not included (typically by providing alternate definitions for all the symbols your application uses in that library module).

- Determine which sections/section fragments from the included modules to include in the application. Only those sections/section fragments that are actually needed by the application are included. There are several ways to determine of which sections/section fragments that are needed, for example, the `__root` object attribute, the `#pragma required` directive, and the `keep` linker directive. In case of duplicate sections, only one is included.
- Where appropriate, arrange for the initialization of initialized variables and code in RAM. The `initialize` directive causes the linker to create extra sections to enable copying from ROM to RAM. Each section that will be initialized by copying is divided into two sections—one for the ROM part, and one for the RAM part. If manual initialization is not used, the linker also arranges for the startup code to perform the initialization.
- Determine where to place each section according to the section placement directives in the *linker configuration file*. Sections that are to be initialized by copying appear twice in the matching against placement directives, once for the ROM part and once for the RAM part, with different attributes.
- Produce an absolute file that contains the executable image and any debug information provided. The contents of each needed section in the relocatable input files is calculated using the relocation information supplied in its file and the addresses determined when placing sections. This process can result in one or more relocation failures if some of the requirements for a particular section are not met, for instance if placement resulted in the destination address for a `PC`-relative jump instruction being out of range for that instruction.
- Optionally, produce a map file that lists the result of the section placement, the address of each global symbol, and finally, a summary of memory usage for each module and library.

This illustration shows the linking process:



During the linking, ILINK might produce error and logging messages on `stdout` and `stderr`. The log messages are useful for understanding why an application was linked as it was. For example, why a module or section (or section fragment) was included.

Note: To see the actual content of an ELF object file, use `ielfdumprh850`. See *The IAR ELF Dumper—ielfdump*, page 489.

Placing code and data—the linker configuration file

The placement of sections in memory is performed by the IAR ILINK Linker. It uses the *linker configuration file* where you can define how ILINK should treat each section and how they should be placed into the available memories.

A typical linker configuration file contains definitions of:

- Available addressable memories
- Populated regions of those memories
- How to treat input sections
- Created sections
- How to place sections into the available regions.

The file consists of a sequence of declarative directives. This means that the linking process will be governed by all directives at the same time.

To use the same source code with different derivatives, just rebuild the code with the appropriate configuration file.

A SIMPLE EXAMPLE OF A CONFIGURATION FILE

Assume a simple 32-bit architecture that has these memory prerequisites:

- There are 4 Gbytes of addressable memory.
- There is ROM memory in the address range `0x0000–0x10000`.
- There is RAM memory in the range `0x20000–0x30000`.
- The stack has an alignment of 8.
- The system startup code must be located at a fixed address.

A simple configuration file for this assumed architecture can look like this:

```
/* The memory space denoting the maximum possible amount
   of addressable memory */
define memory Mem with size = 4G;

/* Memory regions in an address space */
define region ROM = Mem:[from 0x00000 size 0x10000];
define region RAM = Mem:[from 0x20000 size 0x10000];

/* Create a stack */
define block STACK with size = 0x1000, alignment = 8 { };

/* Handle initialization */
initialize by copy { readwrite }; /* Initialize RW sections */

/* Place startup code at a fixed address */
place at start of ROM { readonly section .cstartup };

/* Place code and data */
place in ROM { readonly }; /* Place constants and initializers in
                              ROM: .rodata and .data_init    */
place in RAM { readwrite,  /* Place .data, .bss, and .noinit */
               block STACK }; /* and STACK                   */
```

This configuration file defines one addressable memory `Mem` with the maximum of 4 Gbytes of memory. Furthermore, it defines a ROM region and a RAM region in `Mem`, namely `ROM` and `RAM`. Each region has the size of 64 Kbytes.

The file then creates an empty block called `STACK` with a size of 4 Kbytes in which the application stack will reside. To create a *block* is the basic method which you can use to get detailed control of placement, size, etc. It can be used for grouping sections, but also as in this example, to specify the size and placement of an area of memory.

Next, the file defines how to handle the initialization of variables, read/write type (`readwrite`) sections. In this example, the initializers are placed in ROM and copied at startup of the application to the RAM area. By default, ILINK may compress the initializers if this appears to be advantageous.

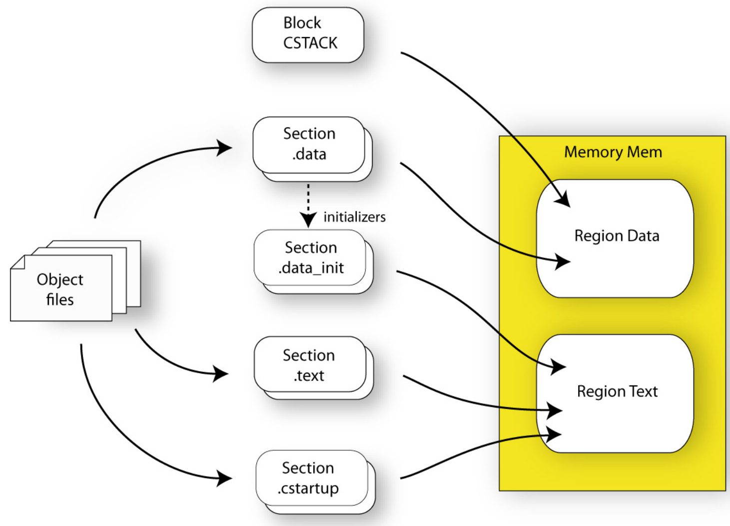
The last part of the configuration file handles the actual placement of all the sections into the available regions. First, the startup code—defined to reside in the read-only (`readonly`) section `.cstartup`—is placed at the start of the `ROM` region, that is at address `0x10000`.

Note: The part within `{}` is referred to as *section selection* and it selects the sections for which the directive should be applied to. Then the rest of the read-only sections are placed in the `ROM` region.

Note: The section selection `{ readonly section .cstartup }` takes precedence over the more generic section selection `{ readonly }`.

Finally, the read/write (`readwrite`) sections and the `STACK` block are placed in the `RAM` region.

This illustration gives a schematic overview of how the application is placed in memory:



In addition to these standard directives, a configuration file can contain directives that define how to:

- Map a memory that can be addressed in multiple ways
- Handle conditional directives
- Create symbols with values that can be used in the application
- More in detail, select the sections a directive should be applied to
- More in detail, initialize code and data.

For more details and examples about customizing the linker configuration file, see the chapter *Linking your application*.

For more information about the linker configuration file, see the chapter *The linker configuration file*.

Initialization at system startup

In Standard C, all static variables—variables that are allocated at a fixed memory address—must be initialized by the runtime system to a known value at application startup. This value is either an explicit value assigned to the variable, or if no value is given, it is cleared to zero. In the compiler, there is one exception to this rule and that is variables declared `__no_init`, which are not initialized at all.

The compiler generates a specific type of section for each type of variable initialization:

Categories of declared data	Source	Section type	Section name	Section content
Zero-initialized data	`int i;`	Read/write data, zero-init	`.*bss*`	None
Zero-initialized data	`int i = 0;`	Read/write data, zero-init	`.*bss*`	None
Initialized data (non-zero)	`int i = 6;`	Read/write data	`.*data*`	The initializer
Non-initialized data	`__no_init int i;`	Read/write data, zero-init	`.*.noinit`	None
Constants	`const int i = 6;`	Read-only data	`.*const*`	The constant

Table 6: Sections holding initialized data

* The actual section name depends on the memory of the variable. For a more information about possible section names, see *Summary of sections*, page 457.

For information about all supported sections, see the chapter *Section reference*.

THE INITIALIZATION PROCESS

Initialization of data is handled by ILINK and the system startup code in conjunction.

To configure the initialization of variables, you must consider these issues:

- Sections that should be zero-initialized, or not initialized at all (`__no_init`) are handled automatically by ILINK.
- Sections that should be initialized, except for zero-initialized sections, should be listed in an `initialize` directive.

  Normally during linking, a section that should be initialized is split into two sections, where the original initialized section will keep the name. The contents are placed in the new initializer section, which will get the original name suffixed with `_init`. The initializers should be placed in ROM and the initialized sections in RAM, by means of placement directives. The most common example is the `.data` section which the linker splits into `.data` and `.data_init`.
- Sections that contains constants should not be initialized—they should only be placed in flash/ROM.

In the linker configuration file, it can look like this:

```
/* Handle initialization */
initialize by copy { readwrite }; /* Initialize RW sections */

/* Place startup code at a fixed address */
place at start of ROM { readonly section .cstartup };

/* Place code and data */
place in ROM { readonly }; /* Place constants and initializers in
                              ROM: .rodata and .data_init    */
place in RAM { readwrite,  /* Place .data, .bss, and .noinit */
               block STACK }; /* and STACK                   */
```

Note: When compressed initializers are used (see *initialize directive*, page 440), the contents sections (that is, sections with the `_init` suffix) are not listed as separate sections in the map file. Instead, they are combined into aggregates of "initializer bytes". You can place the contents sections the usual way in the linker configuration file, however, this affects the placement—and possibly the number—of the "initializer bytes" aggregates.

For more information about and examples of how to configure the initialization, see *Linking considerations*, page 107.

C++ DYNAMIC INITIALIZATION

The compiler places subroutine pointers for performing C++ dynamic initialization into sections of the ELF section types `SHT_PREINIT_ARRAY` and `SHT_INIT_ARRAY`. By default, the linker will place these into a linker-created block, ensuring that all sections of the section type `SHT_PREINIT_ARRAY` are placed before those of the type `SHT_INIT_ARRAY`. If any such sections were included, code to call the routines will also be included.

The linker-created blocks are only generated if the linker configuration does not contain section selector patterns for the `preinit_array` and `init_array` section types. The effect of the linker-created blocks will be very similar to what happens if the linker configuration file contains this:

```
define block SHT$$PREINIT_ARRAY { preinit_array };
define block SHT$$INIT_ARRAY { init_array };
define block CPP_INIT with fixed order { block
                                         SHT$$PREINIT_ARRAY,
                                         block SHT$$INIT_ARRAY };
```

If you put this into your linker configuration file, you must also mention the `CPP_INIT` block in one of the section placement directives. If you wish to select where the linker-created block is placed, you can use a section selector with the name `".init_array"`.

See also *section-selectors*, page 447.

Stack usage analysis

This section describes how to perform a stack usage analysis using the linker.

In the `rh850\src` directory, you can find an example project that demonstrates stack usage analysis.

INTRODUCTION TO STACK USAGE ANALYSIS

Under the right circumstances, the linker can accurately calculate the maximum stack usage for each call graph, starting from the program start, interrupt functions, tasks etc. (each function that is not called from another function, in other words, the root).

If you enable stack usage analysis, a stack usage chapter will be added to the linker map file, listing for each call graph root the particular call chain which results in the maximum stack depth.

The analysis is only accurate if there is accurate stack usage information for each function in the application.

In general, the compiler will generate this information for each C function, but if there are indirect calls—calls using function pointers—in your application, you must supply a list of possible functions that can be called from each calling function.

If you use a stack usage control file, you can also supply stack usage information for functions in modules that do not have stack usage information.

You can use the `check that` directive in your stack usage control file to check that the stack usage calculated by the linker does not exceed the stack space you have allocated.

PERFORMING A STACK USAGE ANALYSIS

1 Enable stack usage analysis:

In the IDE, choose **Project>Options>Linker>Advanced>Enable stack usage analysis**.

On the command line, use the linker option `--enable_stack_usage`.

See *--enable_stack_usage*, page 305.

2 Enable the linker map file:

In the IDE, choose **Project>Options>Linker>List>Generate linker map file**

On the command line, use the linker option `--map`

3 Link your project.

Note: The linker will issue warnings related to stack usage under certain circumstances, see *Situations where warnings are issued*, page 104.

4 Review the linker map file, which now contains a stack usage chapter with a summary of the stack usage for each call graph root. For more information, see *Result of an analysis—the map file contents*, page 100.

5 For more details, analyze the call graph log, see *Call graph log*, page 104.

Note: There are limitations and sources of inaccuracy in the analysis, see *Limitations*, page 103.

You might need to specify more information to the linker to get a more representative result. See *Specifying additional stack usage information*, page 102

In the IDE, choose **Project>Options>Linker>Advanced>Enable stack usage analysis>Control file**.

On the command line, use the linker option `--stack_usage_control`.

See *--stack_usage_control*, page 322.

6 To add an automatic check that you have allocated memory enough for the stack, use the `check that` directive in your linker configuration file. For example, assuming a stack block named `MY_STACK`, you can write like this:

```
check that size(block MY_STACK) >=maxstack("Program entry")
                                + totalstack("interrupt") + 100;
```

When linking, the linker emits an error if the check fails. In this example, an error will be emitted if the sum of the following exceeds the size of the `MY_STACK` block:

- The maximum stack usage in the category `Program entry` (the main program).
- The sum of each individual maximum stack usage in the category `interrupt` (assuming that all interrupt routines need space at the same time).
- A safety margin of 100 bytes (to account for stack usage not visible to the analysis).

See also *check that directive*, page 451 and *Stack considerations*, page 204.

RESULT OF AN ANALYSIS—THE MAP FILE CONTENTS

When stack usage analysis is enabled, the linker map file contains a stack usage chapter with a summary of the stack usage for each call graph root category, and lists the call chain that results in the maximum stack depth for each call graph root. This is an example of what the stack usage chapter in the map file might look like:

```
*****************************************************************
  *** STACK USAGE
  ***

  Call Graph Root Category  Max Use  Total Use
  ------------------------  -------  ---------
  interrupt                     104        136
  Program entry                 168        168

Program entry
  "__iar_program_start": 0x000085ac
  Maximum call chain                        168 bytes

    "__iar_program_start"                     0
    "__cmain"                                 0
    "main"                                    8
    "printf"                                 24
    "_PrintfTiny"                            56
    "_Prout"                                 16
    "putchar"                                16
    "__write"                                 0
    "__dwrite"                                0
    "__iar_sh_stdout"                        24
    "__iar_get_ttio"                         24
    "__iar_lookup_ttioh"                      0

interrupt
  "FaultHandler": 0x00008434

  Maximum call chain                         32 bytes

    "FaultHandler"                           32

interrupt
  "IRQHandler": 0x00008424

  Maximum call chain                        104 bytes

    "IRQHandler"                             24
    "do_something" in suexample.o [1]        80
```

The summary contains the depth of the deepest call chain in each category as well as the sum of the depths of the deepest call chains in that category.

Each call graph root belongs to a call graph root category to enable convenient calculations in `check that` directives.

SPECIFYING ADDITIONAL STACK USAGE INFORMATION

To specify additional stack usage information you can use either a stack usage control file (`suc`) where you specify stack usage control directives or annotate the source code.

You can:

- Specify complete stack usage information (call graph root category, stack usage, and possible calls) for a function, by using the stack usage control directive `function`. Typically, you do this if stack usage information is missing, for example in an assembler module. In your `suc` file you can, for example, write like this:

  ```
  function MyFunc: 32,
    calls MyFunc2,
    calls MyFunc3, MyFunc4: 16;

  function [interrupt] MyInterruptHandler: 44;
  ```

  See also *function directive*, page 476.

- Exclude certain functions from stack usage analysis, by using the stack usage control directive `exclude`. In your `suc` file you can, for example, write like this:

  ```
  exclude MyFunc5, MyFunc6;
  ```

  See also *exclude directive*, page 476.

- Specify a list of possible destinations for indirect calls in a function, by using the stack usage control directive `possible calls`. Use this for functions which are known to perform indirect calls and where you know exactly which functions that might be called in this particular application. In your `suc` file you can, for example, write like this:

  ```
  possible calls MyFunc7: MyFunc8, MyFunc9;
  ```

  If the information about which functions that might be called is available at compile time, consider using the `#pragma calls` directive instead.

  See also *possible calls directive*, page 478 and *calls*, page 362.

- Specify that functions are call graph roots, including an optional call graph root category, by using the stack usage control directive `call graph root` or the `#pragma call_graph_root` directive. In your `suc` file you can, for example, write like this:

  ```
  call graph root [task]: MyFunc10, MyFunc11;
  ```

  If your interrupt functions have not already been designated as call graph roots by the compiler, you must do so manually. You can do this either by using the `#pragma` `call_graph_root` directive in your source code or by specifying a directive in your `suc` file, for example:

```
call graph root [interrupt]: Irq1Handler, Irq2Handler;
```

See also *call graph root directive*, page 476 and *call_graph_root*, page 363.

- Specify a maximum number of iterations through any of the cycles in the recursion nest of which the function is a member. In your `suc` file you can, for example, write like this:

```
max recursion depth MyFunc12: 10;
```

- Selectively suppress the warning about unmentioned functions referenced by a module for which you have supplied stack usage information in the stack usage control file. Use the `no calls from` directive in your `suc` file, for example, like this:

```
no calls from [file.o] to MyFunc13, MyFunc14;
```

- Instead of specifying stack usage information about assembler modules in a stack usage control file, you can annotate the assembler source with call frame information. For more information, see the *IAR Assembler Reference Guide for RH850*.

For more information, see the chapter *The stack usage control file*.

LIMITATIONS

Apart from missing or incorrect stack usage information, there are also other sources of inaccuracy in the analysis:

- The linker cannot always identify all functions in object modules that lack stack usage information. In particular, this might be a problem with object modules written in assembly language or produced by non-IAR tools. You can provide stack usage information for such modules using a stack usage control file, and for assembly language modules you can also annotate the assembler source code with `CFI` directives to provide stack usage information. See the *IAR Assembler Reference Guide for RH850*.
- If you use inline assembler to change the frame size or to perform function calls, this will not be reflected in the analysis.
- Extra space consumed by other sources (the processor, an operating system, etc) is not accounted for.
- If you use other forms of function calls, they will not be reflected in the call graph.
- Using multi-file compilation (`--mfc`) can interfere with using a stack usage control file to specify properties of module-local functions in the involved files.

Note: Stack usage analysis produces a worst case result. The program might not actually ever end up in the maximum call chain, by design, or by coincidence. In particular, the set of possible destinations for a virtual function call in C++ might sometimes include implementations of the function in question which cannot, in fact, be called from that point in the code.

Stack usage analysis is only a complement to actual measurement. If the result is important, you need to perform independent validation of the results of the analysis.

SITUATIONS WHERE WARNINGS ARE ISSUED

When stack usage analysis is enabled in the linker, warnings will be generated in the following circumstances:

- There is a function without stack usage information.
- There is an indirect call site in the application for which a list of possible called functions has not been supplied.
- There are no known indirect calls, but there is an uncalled function that is not known to be a call graph root.
- The application contains recursion (a cycle in the call graph) for which no maximum recursion depth has been supplied, or which is of a form for which the linker is unable to calculate a reliable estimate of stack usage.
- There are calls to a function declared as a call graph root.
- You have used the stack usage control file to supply stack usage information for functions in a module that does not have such information, and there are functions referenced by that module which have not been mentioned as being called in the stack usage control file.

CALL GRAPH LOG

To help you interpret the results of the stack usage analysis, there is a log output option that produces a simple text representation of the call graph (`--log call_graph`).

Example output:

```
Program entry:
0 __iar_program_start [168]
  0 __cmain [168]
    0 __iar_data_init3 [16]
      8 __iar_zero_init3 [8]
        16 - [0]
      8 __iar_copy_init3 [8]
        16 - [0]
    0 __low_level_init [0]
    0 main [168]
      8 printf [160]
        32 _PrintfTiny [136]
          88 _Prout [80]
            104 putchar [64]
              120 __write [48]
                120 __dwrite [48]
                  120 __iar_sh_stdout [48]
                    144 __iar_get_ttio [24]
                      168 __iar_lookup_ttioh [0]
                  120 __iar_sh_write [24]
                    144 - [0]
          88 __aeabi_uidiv [0]
            88 __aeabi_idiv0 [0]
          88 strlen [0]
    0 exit [8]
      0 _exit [8]
        0 __exit [8]
          0 __iar_close_ttio [8]
            8 __iar_lookup_ttioh [0] ***
    0 __exit [8] ***
```

Each line consists of this information:

- The stack usage at the point of call of the function
- The name of the function, or a single '-' to indicate usage in a function at a point with no function call (typically in a leaf function)
- The stack usage along the deepest call chain from that point. If no such value could be calculated, `"[---]"` is output instead. `"***"` marks functions that have already been shown.

CALL GRAPH XML OUTPUT

The linker can also produce a call graph file in XML format. This file contains one node for each function in your application, with the stack usage and call information relevant to that function. It is intended to be input for post-processing tools and is not particularly human-readable.

For more information about the XML format used, see the `callGraph.txt` file in your product installation.

Linking your application

- Linking considerations
- Hints for troubleshooting
- Checking module consistency
- Linker optimizations

Linking considerations

Before you can link your application, you must set up the configuration required by ILINK. Typically, you must consider:

CHOOSING A LINKER CONFIGURATION FILE

The `config` directory contains ready-made linker configuration files for all supported devices. The files contain the information required by ILINK. The only change, if any, you will normally have to make to the supplied configuration file is to customize the start and end addresses of each region so they fit the target system memory map. If, for example, your application uses additional external RAM, you must also add details about the external RAM memory area.

To edit a linker configuration file, use the editor in the IDE, or any other suitable editor.

Do not change the original template file. We recommend that you make a copy in the working directory, and modify the copy instead.

Each project in the IDE should have a reference to one, and only one, linker configuration file. This file can be edited, but for the majority of all projects it is sufficient to configure the vital parameters in **Project>Options>Linker>Config**.

DEFINING YOUR OWN MEMORY AREAS

The default configuration file that you selected has predefined ROM and RAM regions. This example will be used as a starting-point for all further examples in this chapter:

```
/* Define the addressable memory */
define memory Mem with size = 4G;

/* Define a region named ROM with start address 0 and to be 64
Kbytes large */
define region ROM = Mem:[from 0 size 0x10000];

/* Define a region named RAM with start address 0x20000 and to be
64 Kbytes large */
define region RAM = Mem:[from 0x20000 size 0x10000];
```

Each region definition must be tailored for the actual hardware.

To find out how much of each memory that was filled with code and data after linking, inspect the memory summary in the map file (command line option `--map`).

Adding an additional region

To add an additional region, use the `define region` directive, for example:

```
/* Define a 2nd ROM region to start at address 0x80000 and to be
128 Kbytes large */
define region ROM2 = Mem:[from 0x80000 size 0x20000];
```

Merging different areas into one region

If the region is comprised of several areas, use a region expression to merge the different areas into one region, for example:

```
/* Define the 2nd ROM region to have two areas. The first with
the start address 0x80000 and 128 Kbytes large, and the 2nd with
the start address 0xC0000 and 32 Kbytes large */
define region ROM2 = Mem:[from 0x80000 size 0x20000]
                   | Mem:[from 0xC0000 size 0x08000];
```

or equivalently

```
define region ROM2 = Mem:[from 0x80000 to 0xC7FFF]
                     –Mem:[from 0xA0000 to 0xBFFFF];
```

PLACING SECTIONS

The default configuration file that you selected places all predefined sections in memory, but there are situations when you might want to modify this. For example, if you want to place the section that holds constant symbols in the `CONSTANT` region instead of in the default place. In this case, use the `place in` directive, for example:

```
/* Place sections with readonly content in the ROM region */
place in ROM {readonly};

/* Place the constant symbols in the CONSTANT region */
place in CONSTANT {readonly section .rodata};
```

Note: Placing a section—used by the IAR build tools—in a different memory which use a different way of referring to its content, will fail.

For the result of each placement directive after linking, inspect the placement summary in the map file (the command line option `--map`).

Placing a section at a specific address in memory

To place a section at a specific address in memory, use the `place at` directive, for example:

```
/* Place section .vectors at address 0 */
place at address Mem:0x0 {readonly section .vectors};
```

Placing a section first or last in a region

To place a section first or last in a region is similar, for example:

```
/* Place section .vectors at start of ROM */
place at start of ROM {readonly section .vectors};
```

Declare and place your own sections

To declare new sections—in addition to the ones used by the IAR build tools—to hold specific parts of your code or data, use mechanisms in the compiler and assembler. For example:

```
/* Place a variable in that section. */
const short MyVariable @ "MYOWNSECTION" = 0xF0F0;
```

This is the corresponding example in assembler language:

```
            name    createSection
            section MYOWNSECTION:CONST  ; Create a section,
                                        ; and fill it with
            dc16     0xF0F0             ; constant bytes.
            end
```

To place your new section, the original `place in ROM {readonly};` directive is sufficient.

However, to place the section `MyOwnSection` explicitly, update the linker configuration file with a `place in` directive, for example:

```
/* Place MyOwnSection in the ROM region */
place in ROM {readonly section MyOwnSection};
```

RESERVING SPACE IN RAM

Often, an application must have an empty uninitialized memory area to be used for temporary storage, for example, a heap or a stack. It is easiest to achieve this at link time. You must create a block with a specified size and then place it in a memory.

In the linker configuration file, it can look like this:

```
define block TempStorage with size = 0x1000, alignment = 4 { };
place in RAM { block TempStorage };
```

To retrieve the start of the allocated memory from the application, the source code could look like this:

```
/* Define a section for temporary storage. */
#pragma section = "TempStorage"
char *GetTempStorageStartAddress()
{
  /* Return start address of section TempStorage. */
  return __section_begin("TempStorage");
}
```

SHARED RAM AREAS

Multicore devices and some single-core devices have a RAM memory layout where two logical memory areas represent one and the same physical memory. For single-core devices these areas are called Local RAM (mirror) and Local RAM, and for multicore devices they are called Local RAM (self) and Local RAM (CPU *n*). In the linker configuration files, the amount of available RAM is split 50/50 between these areas.

To override this division in the IDE, choose **Project>Options>General Options>Target** and modify the option **Local RAM (self) area size**. The remaining RAM will be allocated to Local RAM or Local RAM (CPU *n*), respectively.

To override this division from the command line, you can set the symbol `_SELF_SIZE` using the linker option `--config_def`, see *--config_def*, page 300.

If not all cores in a multicore system have the same maximum size of Local RAM (self), the value of `_SELF_SIZE` is not allowed to exceed the size of the smallest Local RAM (self) area.

Note: The stack section is located in the Local RAM (self/mirror) area; if you override the default division of shared RAM, make sure to allocate enough space for the stack.

KEEPING MODULES

If a module is linked as an object file, it is always kept. That is, it will contribute to the linked application. However, if a module is part of a library, it is included only if it is symbolically referred to from other parts of the application. This is true, even if the library module contains a root symbol. To assure that such a library module is always included, use `iarchive` to extract the module from the library, see *The IAR Archive Tool—iarchive*, page 483.

For information about included and excluded modules, inspect the log file (the command line option `--log modules`).

For more information about modules, see *Modules and sections*, page 90.

KEEPING SYMBOLS AND SECTIONS

By default, ILINK removes any sections, section fragments, and global symbols that are not needed by the application. To retain a symbol that does not appear to be needed—or actually, the section fragment it is defined in—you can either use the root attribute on the symbol in your C/C++ or assembler source code, or use the ILINK option `--keep`. To retain sections based on attribute names or object names, use the directive `keep` in the linker configuration file.

To prevent ILINK from excluding sections and section fragments, use the command line options `--no_remove` or `--no_fragments`, respectively.

For information about included and excluded symbols and sections, inspect the log file (the command line option `--log sections`).

For more information about the linking procedure for keeping symbols and sections, see *The linking process*, page 56.

APPLICATION STARTUP

The point where the application starts execution is defined by a start label, see *Building applications—an overview*, page 63. The label is also communicated via ELF to any debugger that is used.

To change the start point of the application to another label, use the ILINK option `--entry`, see *--entry*, page 306.

SETTING UP STACK MEMORY

The size of the `CSTACK` block is defined in the linker configuration file. To change the allocated amount of memory, change the block definition for `CSTACK`:

```
define block CSTACK with size = 0x2000, alignment = 8{ };
```

Specify an appropriate size for your application.

For more information about the stack, see *Stack considerations*, page 204.

SETTING UP HEAP MEMORY

The size of the heap is defined in the linker configuration file as a block:

```
define block HEAP with size = _HEAP_SIZE, alignment = 8{ };
place in RAM {block HEAP};
```

Specify the appropriate size for the symbol `HEAP_SIZE`. If you use a heap, you must allocate at least 50 bytes for it.

For more information, see *Advanced, basic, and no-free heap*, page 204.

SETTING UP THE ATEXIT LIMIT

By default, the `atexit` function can be called a maximum of 32 times from your application. To either increase or decrease this number, add a line to your configuration file. For example, to reserve room for 10 calls instead, write:

```
define symbol __iar_maximum_atexit_calls = 10;
```

CHANGING THE DEFAULT INITIALIZATION

By default, memory initialization is performed during application startup. ILINK sets up the initialization process and chooses a suitable packing method. If the default initialization process does not suit your application and you want more precise control over the initialization process, these alternatives are available:

- Suppressing initialization
- Choosing the packing algorithm
- Manual initialization
- Initializing code—copying ROM to RAM.

For information about the performed initializations, inspect the log file (the command line option `--log initialization`).

Suppressing initialization

If you do not want the linker to arrange for initialization by copying, for some or all sections, make sure that those sections do not match a pattern in an `initialize by copy` directive—or use an `except` clause to exclude them from matching. If you do not want any initialization by copying at all, you can omit the `initialize by copy` directive entirely.

This can be useful if your application, or just your variables, are loaded into RAM by some other mechanism before application startup.

Choosing a packing algorithm

To override the default packing algorithm, write for example:

```
initialize by copy with packing = lz77 { readwrite };
```

For more information about the available packing algorithms, see *initialize directive*, page 440.

Manual initialization

In the usual case, the `initialize by copy` directive is used for making the linker arrange for initialization by copying—with or without packing—of sections with content at application startup. The linker achieves this by logically creating an initialization section for each such section, holding the content of the section, and turning the original section into a section without content. Then, the linker adds table elements to the initialization table so that the initialization will be performed at application startup. You can use `initialize manually` to suppress the creation of table elements to take control over when and how the elements are copied. This is useful for overlays, but also in other circumstances.

For sections without content (zero-initialized sections), the situation is reversed. The linker arranges for zero initialization of all such sections at application startup, except for those that are mentioned in a `do not initialize` directive.

Simple copying example with an automatic block

Assume that you have some initialized variables in `MYSECTION`. If you add this directive to your linker configuration file:

```
initialize manually { section MYSECTION };
```

you can use this source code example to initialize the section:

```
#pragma section = "MYSECTION"
#pragma section = "MYSECTION_init"

void DoInit()
{
  char * from = __section_begin("MYSECTION_init");
  char * to   = __section_begin("MYSECTION");
  memcpy(to, from, __section_size("MYSECTION"));
}
```

This piece of source code takes advantage of the fact that if you use `__section_begin` (and related operators) with a section name, an automatic block is created by the linker for those sections.

Note: Automatic blocks override the normal section selection process and forces everything that matches the section name to form on block.

Example with explicit blocks

Assume that you instead of needing manual initialization for variables in a specific section, you need it for all initialized variables from a particular library. In that case, you must create explicit blocks for both the variables and the content. Like this:

```
initialize manually       { section .data      object mylib.a };
define block MYBLOCK      { section .data      object mylib.a };
define block MYBLOCK_init { section .data_init object mylib.a };
```

You must also place the two new blocks using one of the section placement directives, the block `MYBLOCK` in RAM and the block `MYBLOCK_init` in ROM.

Then you can initialize the sections using the same source code as in the previous example, only with `MYBLOCK` instead of `MYSECTION`.

Overlay example

This is a simple overlay example that takes advantage of automatic block creation:

```
initialize manually { section MYOVERLAY* };

define overlay MYOVERLAY { section MYOVERLAY1 };
define overlay MYOVERLAY { section MYOVERLAY2 };
```

You must also place `overlay MYOVERLAY` somewhere in RAM. The copying could look like this:

```
#pragma section = "MYOVERLAY"
#pragma section = "MYOVERLAY1_init"
#pragma section = "MYOVERLAY2_init"

void SwitchToOverlay1()
{
  char * from = __section_begin("MYOVERLAY1_init");
  char * to   = __section_begin("MYOVERLAY");
  memcpy(to, from, __section_size("MYOVERLAY1_init"));
}

void SwitchToOverlay2()
{
  char * from = __section_begin("MYOVERLAY2_init");
  char * to   = __section_begin("MYOVERLAY");
  memcpy(to, from, __section_size("MYOVERLAY2_init"));
}
```

Initializing code—copying ROM to RAM

Sometimes, an application copies pieces of code from flash/ROM to RAM. You can direct the linker to arrange for this to be done automatically at application startup, or do it yourself at some later time using the techniques described in *Manual initialization*, page 113.

You need to list the code sections that should be copied in an `initialize by copy` directive. The easiest way is usually to place the relevant functions in a particular section—for example, `RAMCODE`— and add `section RAMCODE` to your `initialize by copy` directive. For example:

```
initialize by copy { rw, section RAMCODE };
```

If you need to place the `RAMCODE` functions in some particular location, you must mention them in a placement directive, otherwise they will be placed together with other read/write sections.

If you need to control the manner and/or time of copying, you must use an `initialize manually` directive instead. See *Manual initialization*, page 113.

Running all code from RAM

If you want to copy the entire application from ROM to RAM at program startup, use the `initilize by copy` directive, for example:

```
initialize by copy { readonly, readwrite };
```

The `readwrite` pattern will match all statically initialized variables and arrange for them to be initialized at startup. The `readonly` pattern will do the same for all read-only code and data, except for code and data needed for the initialization.

Because the function `__low_level_init`, if present, is called before initialization, it and anything it needs, will not be copied from ROM to RAM either. In some circumstances—for example, if the ROM contents are no longer available to the program after startup—you might need to avoid using the same functions during startup and in the rest of the code.

If anything else should not be copied, include it in an `except` clause. This can apply to, for example, the interrupt vector table.

It is also recommended to exclude the C++ dynamic initialization table from being copied to RAM, as it is typically only read once and then never referenced again. For example, like this:

```
initialize by copy { readonly, readwrite }
            except { section .intvec,      /* Don’t copy
                                               interrupt table */
                     section .init_array }; /* Don’t copy
                                               C++ init table */
```

INTERACTION BETWEEN ILINK AND THE APPLICATION

ILINK provides the command line options `--config_def` and `--define_symbol` to define symbols which can be used for controlling the application. You can also use symbols to represent the start and end of a continuous memory area that is defined in the linker configuration file. For more information, see *Interaction between the tools and your application*, page 207.

To change a reference to one symbol to another symbol, use the ILINK command line option `--redirect`. This is useful, for example, to redirect a reference from a non-implemented function to a stub function, or to choose one of several different implementations of a certain function, for example, how to choose the DLIB formatter for the standard library functions `printf` and `scanf`.

The compiler generates mangled names to represent complex C/C++ symbols. If you want to refer to these symbols from assembler source code, you must use the mangled names.

For information about the addresses and sizes of all global (statically linked) symbols, inspect the entry list in the map file (the command line option `--map`).

For more information, see *Interaction between the tools and your application*, page 207.

STANDARD LIBRARY HANDLING

By default, ILINK determines automatically which variant of the standard library to include during linking. The decision is based on the sum of the runtime attributes available in each object file and the library options passed to ILINK.

To disable the automatic inclusion of the library, use the option `--no_library_search`. In this case, you must explicitly specify every library file to be included. For information about available library files, see *Prebuilt runtime libraries*, page 135.

PRODUCING OUTPUT FORMATS OTHER THAN ELF/DWARF

ILINK can only produce an output file in the ELF/DWARF format. To convert that format into a format suitable for programming PROM/flash, see *The IAR ELF Tool—ielftool*, page 486.

Hints for troubleshooting

ILINK has several features that can help you manage code and data placement correctly, for example:

- Messages at link time, for examples when a relocation error occurs
- The `--log` option that makes ILINK log information to `stdout`, which can be useful to understand why an executable image became the way it is, see *--log*, page 311
- The `--map` option that makes ILINK produce a memory map file, which contains the result of the linker configuration file, see *--map*, page 313.

RELOCATION ERRORS

For each instruction that cannot be relocated correctly, ILINK will generate a *relocation error*. This can occur for instructions where the target is out of reach or is of an incompatible type, or for many other reasons.

A relocation error produced by ILINK can look like this:

```
Error[Lp002]: relocation failed: out of range or illegal value
    Kind     :   R_XXX_YYY[0x1]
    Location :   0x40000448
                 "myfunc" + 0x2c
                 Module:  somecode.o
                 Section: 7 (.text)
                 Offset:  0x2c
    Destination: 0x9000000c
                 "read"
                 Module:  read.o(iolib.a)
                 Section: 6 (.text)
                 Offset:  0x0
```

The message entries are described in this table:

Message entry	Description
`Kind`	The relocation directive that failed. The directive depends on the instruction used.
`Location`	The location where the problem occurred, described with the following details: • The instruction address, expressed both as a hexadecimal value and as a label with an offset. In this example, `0x40000448` and `"myfunc" + 0x2c`. • The module, and the file. In this example, the module `somecode.o`. • The section number and section name. In this example, section number `7` with the name `.text`. • The offset, specified in number of bytes, in the section. In this example, `0x2c`.
`Destination`	The target of the instruction, described with the following details: • The instruction address, expressed both as a hexadecimal value and as a label with an offset. In this example, `0x9000000c` and "read"—therefore, no offset. • The module, and when applicable the library. In this example, the module `read.o` and the library `iolib.a`. • The section number and section name. In this example, section number `6` with the name `.text`. • The offset, specified in number of bytes, in the section. In this example, `0x0`.

Table 7: Description of a relocation error

Possible solutions

In this case, the distance from the instruction in `myfunc` to `__read` is too long for the branch instruction.

Possible solutions include ensuring that the two `.text` sections are allocated closer to each other or using some other calling mechanism that can reach the required distance. It is also possible that the referring function tried to refer to the wrong target and that this caused the range error.

Different range errors have different solutions. Usually, the solution is a variant of the ones presented above, in other words modifying either the code or the section placement.

Checking module consistency

This section introduces the concept of runtime model attributes, a mechanism used by the tools provided by IAR Systems to ensure that modules that are linked into an application are compatible, in other words, are built using compatible settings. The tools use a set of predefined runtime model attributes. In addition to these, you can define your own that you can use to ensure that incompatible modules are not used together.

For example, in the compiler, you can specify a data model. If you write a routine that only works for the Near data model, it is possible to check that the routine is not used in an application built using the Huge data model.

RUNTIME MODEL ATTRIBUTES

A runtime attribute is a pair constituted of a named key and its corresponding value. In general, two modules can only be linked together if they have the same value for each key that they both define.

There is one exception: if the value of an attribute is `*`, then that attribute matches any value. The reason for this is that you can specify this in a module to show that you have considered a consistency property, and this ensures that the module does not rely on that property.

Note: For IAR predefined runtime model attributes, the linker checks them in several ways.

Example

In this table, the object files could (but do not have to) define the two runtime attributes `color` and `taste`:

Object file	Color	Taste
`file1`	`blue`	not defined
`file2`	`red`	not defined
`file3`	`red`	`*`
`file4`	`red`	`spicy`
`file5`	`red`	`lean`

Table 8: Example of runtime model attributes

In this case, `file1` cannot be linked with any of the other files, since the runtime attribute `color` does not match. Also, `file4` and `file5` cannot be linked together, because the `taste` runtime attribute does not match.

On the other hand, `file2` and `file3` can be linked with each other, and with either `file4` or `file5`, but not with both.

USING RUNTIME MODEL ATTRIBUTES

To ensure module consistency with other object files, use the `#pragma rtmodel` directive to specify runtime model attributes in your C/C++ source code. For example, if you have a UART that can run in two modes, you can specify a runtime model attribute, for example `uart`. For each mode, specify a value, for example `mode1` and `mode2`. Declare this in each module that assumes that the UART is in a particular mode. This is how it could look like in one of the modules:

```
#pragma rtmodel="uart", "mode1"
```

Alternatively, you can also use the `rtmodel` assembler directive to specify runtime model attributes in your assembler source code. For example:

```
        rtmodel "uart", "mode1"
```

Note: Key names that start with two underscores are reserved by the compiler. For more information about the syntax, see *rtmodel*, page 378 and the *IAR Assembler Reference Guide for RH850*.

At link time, the IAR ILINK Linker checks module consistency by ensuring that modules with conflicting runtime attributes will not be used together. If conflicts are detected, an error is issued.

Linker optimizations

This section contains information about:

- *Virtual function elimination*, page 121
- *Small function inlining*, page 121
- *Duplicate section merging*, page 122

VIRTUAL FUNCTION ELIMINATION

Virtual Function Elimination (VFE) is a linker optimization that removes unneeded virtual functions and dynamic runtime type information.

In order for Virtual Function Elimination to work, all relevant modules must provide information about virtual function table layout, which virtual functions are called, and for which classes dynamic runtime type information is needed. If one or more modules do not provide this information, a warning is generated by the linker and Virtual Function Elimination is not performed.

If you know that modules that lack such information do not perform any virtual function calls and do not define any virtual function tables, you can use the `--vfe=forced` linker option to enable Virtual Function Elimination anyway.

In the IDE, select **Project>Options>Linker>Optimizations>Perform C++ Virtual Function Elimination** to enable this optimization.

Currently, tools from IAR Systems provide the information needed for Virtual Function Elimination in a way that the linker can use.

Note: You can disable Virtual Function Elimination entirely by using the `--no_vfe` linker option. In this case, no warning will be issued for modules that lack VFE information.

For more information, see *--vfe*, page 324 and *--no_vfe*, page 317.

SMALL FUNCTION INLINING

Small function inlining is a linker optimization that replaces some calls to small functions with the body of the function. This requires the body to fit in the space of the instruction that calls the function.

In the IDE, select **Project>Options>Linker>Optimizations>Inline small routines** to enable this optimization.

Use the linker option `--inline`.

DUPLICATE SECTION MERGING

The linker can detect read-only sections with identical contents and keep only one copy of each such section, redirecting all references to any of the duplicate sections to the retained section.

In the IDE, select **Project>Options>Linker>Optimizations>Merge duplicate sections** to enable this optimization.

Use the linker option `--merge_duplicate_sections`.

Note: This optimization can cause different functions or constants to have the same address, so if your application depends on the addresses being different, for example, by using the addresses as keys into a table, you should not enable this optimization.

The DLIB runtime environment

- Introduction to the runtime environment
- Setting up the runtime environment
- Additional information on the runtime environment
- Managing a multithreaded environment

Introduction to the runtime environment

A *runtime environment* is the environment in which your application executes.

This section contains information about:

- *Runtime environment functionality*, page 123
- *Briefly about input and output (I/O)*, page 124
- *Briefly about C-SPY emulated I/O*, page 126
- *Briefly about retargeting*, page 126

RUNTIME ENVIRONMENT FUNCTIONALITY

The *DLIB runtime environment* supports Standard C and C++ and consists of:

- The *C/C++ standard library*, both its interface (provided in the system header files) and its implementation.
- Startup and exit code.
- Low-level I/O interface for managing input and output (I/O).
- Special compiler support, for instance functions for switch handling or integer arithmetics.
- Support for hardware features:
  - Direct access to low-level processor operations by means of *intrinsic* functions, such as functions for interrupt mask handling
  - Peripheral unit registers and interrupt definitions in include files
  - Target-specific support for a floating-point coprocessor with single or double precision.

Runtime environment functions are provided in one or more *runtime libraries*.

The runtime library is delivered both as prebuilt libraries and (depending on your product package) as source files. The prebuilt libraries are available in different *configurations* to meet various needs, see *Runtime library configurations*, page 134. You can find the libraries in the product subdirectories `rh850\lib` and `rh850\src\lib`, respectively.

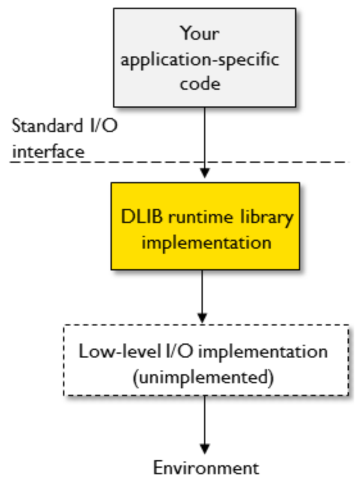
For more information about the library, see the chapter *C/C++ standard library functions*.

BRIEFLY ABOUT INPUT AND OUTPUT (I/O)

Every application must communicate with its environment. The application might for example display information on an LCD, read a value from a sensor, get the current date from the operating system, etc. Typically, your application performs I/O via the C/C++ standard library or some third-party library.

There are many functions in the C/C++ standard library that deal with I/O, including functions for: standard character streams, file system access, time and date, miscellaneous system actions, and termination and assert. This set of functions is referred to as the *standard I/O interface*.

On a desktop computer or a server, the operating system is expected to provide I/O functionality to the application via the standard I/O interface in the runtime environment. However, in an embedded system, the runtime library cannot assume that such functionality is present, or even that there is an operating system at all. Therefore, the low-level part of the standard I/O interface is not completely implemented by default:



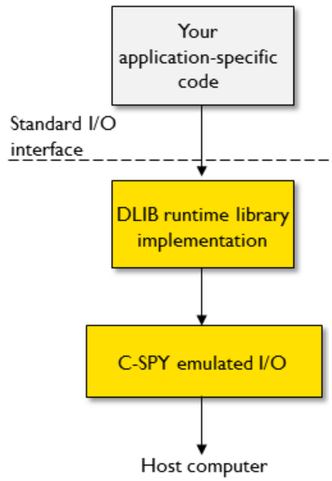
To make the standard I/O interface work, you can:

- Let the C-SPY debugger emulate I/O operations on the host computer, see *Briefly about C-SPY emulated I/O*, page 126
- *Retarget* the standard I/O interface to your target system by providing a suitable implementation of the interface, see *Briefly about retargeting*, page 126.

It is possible to mix these two approaches. You can, for example, let debug printouts and asserts be emulated by the C-SPY debugger, but implement your own file system. The debug printouts and asserts are useful during debugging, but no longer needed when running the application stand-alone (not connected to the C-SPY debugger).

BRIEFLY ABOUT C-SPY EMULATED I/O

C-SPY emulated I/O is a mechanism which lets the runtime environment interact with the C-SPY debugger to emulate I/O actions on the host computer:



For example, when C-SPY emulated I/O is enabled:

- Standard character streams are directed to the C-SPY **Terminal I/O** window
- File system operations are performed on the host computer
- Time and date functions return the time and date of the host computer
- The C-SPY debugger notifies when the application terminates or an assert fails.

This behavior can be valuable during the early development of an application, for example in an application that uses file I/O before any flash file system I/O drivers are implemented, or if you need to debug constructions in your application that use `stdin` and `stdout` without the actual hardware device for input and output being available.

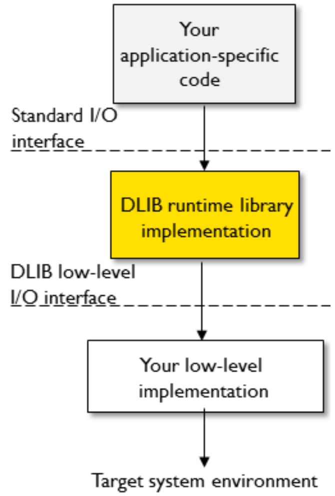
See *Setting up your runtime environment*, page 128 and *The C-SPY emulated I/O mechanism*, page 141.

BRIEFLY ABOUT RETARGETING

Retargeting is the process where you adapt the runtime environment so that your application can execute I/O operations on your target system.

The standard I/O interface is large and complex. To make retargeting easier, the DLIB runtime environment is designed so that it performs all I/O operations through a small set of simple functions, which is referred to as the *DLIB low-level I/O interface*. By default, the functions in the low-level interface lack usable implementations. Some are unimplemented, others have stub implementations that do not perform anything except returning error codes.

To retarget the standard I/O interface, all you have to do is to provide implementations for the functions in the DLIB low-level I/O interface.



For example, if your application calls the functions `printf` and `fputc` in the standard I/O interface, the implementations of those functions both call the low-level function `__write` to output individual characters. To make them work, you just need to provide an implementation of the `__write` function—either by implementing it yourself, or by using a third-party implementation.

For information about how to override library modules with your own implementations, see *Overriding library modules*, page 131. See also *The DLIB low-level I/O interface*, page 147 for information about the functions that are part of the interface.

Setting up the runtime environment

This section contains these tasks:

- *Setting up your runtime environment*, page 128

  A runtime environment with basic project settings to be used during the initial phase of development.

- *Retargeting—Adapting for your target system*, page 129
- *Overriding library modules*, page 131

- *Customizing and building your own runtime library*, page 132

See also:

- *Managing a multithreaded environment*, page 158 for information about how to adapt the runtime environment to treat all library objects according to whether they are global or local to a thread.

SETTING UP YOUR RUNTIME ENVIRONMENT

You can set up the runtime environment based on some basic project settings. It is also often convenient to let the C-SPY debugger manage things like standard streams, file I/O, and various other system interactions. This basic runtime environment can be used for simulation before you have any target hardware.

To set up the runtime environment:

1 Before you build your project, choose **Project>Options>General Options** to open the **Options** dialog box.

2 On the **Library Configuration** page, verify the following settings:

- **Library**: choose which *library configuration* to use. Typically, choose **Tiny**, **Normal**, or **Full**.

  For information about the various library configurations, see *Runtime library configurations*, page 134.

3 On the **Library Options** page, select **Auto with multibyte support** or **Auto without multibyte support** for both **Printf formatter** and **Scanf formatter**. This means that the linker will automatically choose the appropriate formatters based on information from the compiler. For more information about the available formatters and how to choose one manually, see *Formatters for printf*, page 138 and *Formatters for scanf*, page 139, respectively.

4 To enable C-SPY emulated I/O, choose **Project>Options>Linker>Library** and select **Include C-SPY debugging support**. See *Briefly about C-SPY emulated I/O*, page 126.

On the command line, use the linker option `--debug_lib`.

Note: The C-SPY **Terminal I/O** window is not opened automatically; you must open it manually. For more information about this window, see the *C-SPY® Debugging Guide for RH850*.

Note: If you enable debug information before compiling, this information will be included also in the linker output, unless you use the linker option `--strip`.

5 On some systems, terminal output might be slow because the host computer and the target system must communicate for each character.

For this reason, a replacement for the `__write` function called `__write_buffered` is included in the runtime library. This module buffers the output and sends it to the debugger one line at a time, speeding up the output.

Note: This function uses about 80 bytes of RAM memory.

To use this feature in the IDE, choose **Project>Options>Linker>Library** and select the option **Buffered write**.

To enable this function on the command line, add this to the linker command line:

```
--redirect ___write=___write_buffered
```

6 Some math functions are available in different versions: default versions, smaller than the default versions, and larger but more accurate than default versions. Consider which versions you should use.

To specify which set of the math functions to use, choose **Project>Options>General Options>Library Options>Math functions** and choose which set to use. You can also specify individual functions.

For more information, see *Math functions*, page 141.

7 When you build your project, a suitable prebuilt library and library configuration file are automatically used based on the project settings you made.

For information about which project settings affect the choice of library file, see *Runtime library configurations*, page 134.

You have now set up a runtime environment that can be used while developing your application source code.

RETARGETING—ADAPTING FOR YOUR TARGET SYSTEM

Before you can run your application on your target system, you must adapt some parts of the runtime environment, typically the system initialization and the DLIB low-level I/O interface functions.

To adapt your runtime environment for your target system:

1 Adapt system initialization.

It is likely that you must adapt the system initialization, for example, your application might need to initialize interrupt handling, I/O handling, watchdog timers, etc. You do this by implementing the routine `__low_level_init`, which is executed before the data sections are initialized. See *System startup and termination*, page 142 and *System initialization*, page 146.

Note: You can find device-specific examples on this in the example projects provided in the product installation, see the Information Center.

2 Adapt the runtime library for your target system. To implement such functions, you need a good understanding of the DLIB low-level I/O interface, see *Briefly about retargeting*, page 126.

Typically, you must implement your own functions if your application uses:

- Standard streams for input and output

  If any of these streams are used by your application, for example by the functions `printf` and `scanf`, you must implement your versions of the low-level functions `__read` and `__write`.

  The low-level functions identify I/O streams, such as an open file, with a file handle that is a unique integer. The I/O streams normally associated with `stdin`, `stdout`, and `stderr` have the file handles `0`, `1`, and `2`, respectively. When the handle is `-1`, all streams should be flushed. Streams are defined in `stdio.h`.

- File input and output

  The library contains a large number of powerful functions for file I/O operations, such as `fopen`, `fclose`, `fprintf`, `fputs`, etc. All these functions call a small set of low-level functions, each designed to accomplish one particular task, for example, `__open` opens a file, and `__write` outputs characters. Implement your version of these low-level functions.

- `signal` and `raise`

  If the default implementation of these functions does not provide the functionality you need, you can implement your own versions.

- Time and date

  To make the time and date functions work, you must implement the functions `clock`, `__time32`, `__time64`, and `__getzone`. Whether you use `__time32` or `__time64` depends on which interface you use for `time_t`, see *time.h*, page 421.

- Assert, see *__iar_ReportAssert*, page 151.
- Environment interaction

  If the default implementation of `system` or `getenv` does not provide the functionality you need, you can implement your own versions.

For more information about the functions, see *The DLIB low-level I/O interface*, page 147.

The library files that you can override with your own versions are located in the `rh850\src\lib` directory.

3 When you have implemented your functions of the low-level I/O interface, you must add your version of these functions to your project. For information about this, see *Overriding library modules*, page 131.

Note: If you have implemented a DLIB low-level I/O interface function and added it to a project that you have built with support for C-SPY emulated I/O, your low-level function will be used and not the functions provided with C-SPY emulated I/O. For example, if you implement your own version of `__write`, output to the C-SPY **Terminal I/O** window will not be supported. See *Briefly about C-SPY emulated I/O*, page 126.

4 Before you can execute your application on your target system, you must rebuild your project with a Release build configuration. This means that the linker will not include the C-SPY emulated I/O mechanism and the low-level I/O functions it provides. If your application calls any of the low-level functions of the standard I/O interface, either directly or indirectly, and your project does not contain these, the linker will issue an error for every missing low-level function.

Note: By default, the `NDEBUG` symbol is defined in a Release build configuration, which means asserts will no longer be checked. For more information, see *__iar_ReportAssert*, page 151.

OVERRIDING LIBRARY MODULES

To override a library function and replace it with your own implementation:

1 Use a template source file—a library source file or another template—and place a copy of it in your project directory.

The library files that you can override with your own versions are located in the `rh850\src\lib` directory.

2 Modify the file.

Note: To override the functions in a module, you must provide alternative implementations for all the needed symbols in the overridden module. Otherwise you will get error messages about duplicate definitions.

3 Add the modified file to your project, like any other source file.

Note: If you have implemented a DLIB low-level I/O interface function and added it to a project that you have built with support for C-SPY emulated I/O, your low-level function will be used and not the functions provided with C-SPY emulated I/O. For example, if you implement your own version of `__write`, output to the C-SPY **Terminal I/O** window will not be supported. See *Briefly about C-SPY emulated I/O*, page 126.

You have now finished the process of overriding the library module with your version.

CUSTOMIZING AND BUILDING YOUR OWN RUNTIME LIBRARY

If the prebuilt library configurations do not meet your requirements, you can customize your own library configuration, but that requires that you *rebuild* relevant parts of the library.

Note: Customizing and building your own runtime library requires access to the library source code, which is not available for all types of IAR Embedded Workbench licenses.

Building a customized library is a complex process. Therefore, consider carefully whether it is really necessary. You must build your own runtime library when:

- You want to define your own library configuration with support for locale, file descriptors, multibyte characters, etc. This will include or exclude certain parts of the DLIB runtime environment.

In those cases, you must:

- Make sure that you have installed the library source code (`src\lib`). If not already installed, you can install it using the IAR License Manager, see the *Installation and Licensing Guide*.
- Set up a library project
- Make the required library customizations
- Build your customized runtime library
- Finally, make sure your application project will use the customized runtime library.

To set up a library project:

1 In the IDE, choose **Project>Create New Project** and use any of the library project templates that are available for the prebuilt libraries and that matches the project settings you need as closely as possible. See *Prebuilt runtime libraries*, page 135.

Note: When you create a new library project from a template, the majority of the files included in the new project are the original installation files. If you are going to modify these files, make copies of them first and replace the original files in the project with these copies.

2 Modify the generic options in the created library project to suit your application, see *Basic project configuration*, page 64.

To customize the library functionality:

1 The library functionality is determined by a set of *configuration symbols*. The default values of these symbols are defined in the file `DLib_Defaults.h` which you can find in `rh850\inc\c`. This read-only file describes the configuration possibilities. Note that you should not modify this file.

In addition, you can create your own *library configuration file* by making a copy of the file `DLib_Config_`*`configuration`*`.h`—which you can find in the `rh850\inc\c` directory—and customize it by setting the values of the configuration symbols according to the application requirements.

For information about configuration symbols that you might want to customize, see:

- *Configuration symbols for file input and output*, page 156
- *Locale*, page 157
- *Strtod*, page 158
- *Managing a multithreaded environment*, page 158

2 When you are finished, build your library project with the appropriate project options.

After you build your library, you must make sure to use it in your application project.

To build IAR Embedded Workbench projects from the command line, use the IAR Command Line Build Utility (`iarbuild.exe`). However, no make or batch files for building the library from the command line are provided. For information about the build process and the IAR Command Line Build Utility, see the *IDE Project Management and Building Guide for RH850*.

To use the customized runtime library in your application project:

1 In the IDE, choose **Project>Options>General Options** and click the **Library Configuration** tab.

2 From the **Library** drop-down menu, choose **Custom**.

3 In the **Configuration file** text box, locate your library configuration file.

4 Click the **Library** tab, also in the **Linker** category. Use the **Additional libraries** text box to locate your library file.

Additional information on the runtime environment

This section gives additional information on the runtime environment:

- *Bounds checking functionality*, page 134
- *Runtime library configurations*, page 134
- *Prebuilt runtime libraries*, page 135
- *Formatters for printf*, page 138
- *Formatters for scanf*, page 139
- *The C-SPY emulated I/O mechanism*, page 141
- *Math functions*, page 141

- *System startup and termination*, page 142
- *System initialization*, page 146
- *The DLIB low-level I/O interface*, page 147
- *Configuration symbols for file input and output*, page 156
- *Locale*, page 157
- *Strtod*, page 158

BOUNDS CHECKING FUNCTIONALITY

To enable the bounds checking functions specified in Annex K (*Bounds-checking interfaces*) of the C standard, define the preprocessor symbol `__STDC_WANT_LIB_EXT1__` to `1` prior to including any system headers. See *C bounds-checking interface*, page 420.

RUNTIME LIBRARY CONFIGURATIONS

The runtime library is provided with different *library configurations*, where each configuration is suitable for different application requirements.

The runtime library configuration is defined in the *library configuration file*. It contains information about what functionality is part of the runtime environment. The less functionality you need in the runtime environment, the smaller the environment becomes.

These predefined library configurations are available:

Library configuration	Description
Normal DLIB (default)	C locale, but no locale interface, no file descriptor support, no multibyte characters in `printf` and `scanf`, and no hexadecimal floating-point numbers in `strtod`.
Full DLIB	Full locale interface, C locale, file descriptor support, and optionally multibyte characters in `printf` and `scanf`, and hexadecimal floating-point numbers in `strtod`.

Table 9: Library configurations

Note: In addition to these predefined library configurations, you can provide your own configuration, see *Customizing and building your own runtime library*, page 132

If you do not specify a library configuration explicitly you will get the default configuration. If you use a prebuilt runtime library, a configuration file that matches the runtime library file will automatically be used. See *Setting up the runtime environment*, page 127.

To override the default library configuration, use one of these methods:

1 Use a prebuilt configuration of your choice—to specify a runtime configuration explicitly:

Choose **Project>Options>General Options>Library Configuration>Library** and change the default setting.

Use the `--dlib_config` compiler option, see *--dlib_config*, page 266.

The prebuilt libraries are based on the default configurations, see *Runtime library configurations*, page 134.

2 If you have built your own customized library, choose **Project>Options>Library Configuration>Library** and choose **Custom** to use your own configuration. For more information, see *Customizing and building your own runtime library*, page 132.

PREBUILT RUNTIME LIBRARIES

The prebuilt runtime libraries are configured for different combinations of these options:

- CPU core
- Alignment
- Floating-point unit
- Size of the `double` floating-point type
- Library configuration—Normal or Full.

The linker will automatically include the correct library object file and library configuration file. To explicitly specify a library configuration, use the `--dlib_config` compiler option.

Library filename syntax

The names of the libraries are constructed from these elements:

{*library*}	`dl` for the IAR DLIB runtime environment
{*cpu*}	`rh` for the RH850 microcontroller
{*core*}	Specifies the CPU core: `3` = the RH850 G3 core `4` = the RH850 G4 core
{*code_model*}	Specifies the code model and is set to `n`. The compiler does not support code models. This part of the library name is for forward compatibility.
{*alignment*}	Specifies the alignment: `4` = 4-byte alignment `8` = 8-byte alignment
{*size_of_double*}	Specifies the size of `double`: `f` = 32 bits `d` = 64 bits
{*fpu*}	Specifies the FPU support: empty = no FPU `fpu32` = FPU with single floating-point precision `fpu64` = FPU with double floating-point precision
{*lib_config*}	Specifies the library configuration: `n` = Normal `f` = Full
{*debug_io*}	Specifies the support for C-SPY emulated I/O: `d` = support for C-SPY emulated I/O `n` = no support for C-SPY emulated I/O

You can find the library object files and the library configuration files in the subdirectory `rh850\lib\`.

Groups of library files

The libraries are delivered in groups of library functions:

Library files for C/C++ standard library functions

These are the functions defined by Standard C and C++, for example functions like `printf` and `scanf`.

The names of the library files are constructed in the following way:

`dlrh{`*`core`*`}{`*`code_model`*`}{`*`alignment`*`}{`*`size_of_double`*`}{`*`fpu`*`}{`*`lib_config`*`}.a`

which more specifically means

`dlrh{3|4}n{4|8}{f|d}{|fpu32|fpu64}{n|f}.a`

Example: `dlrh3n8dfpu64n.a`

Library files for C-SPY emulated I/O

These are functions for C-SPY emulated I/O.

The names of the library files are constructed in the following way:

`dbgrh{`*`core`*`}{`*`code_model`*`}{`*`alignment`*`}{`*`size_of_double`*`}{`*`fpu`*`}{`*`lib_config`*`}}{`*`debug_io`*`}.a`

which more specifically means

`dbgrh{3|4}n{4|8}{f|d}{|fpu32|fpu64}{n|f}{d|n}.a`

Example: `dbgrh3n4ffpu32fn.a`

Library files for thread support

These are the functions for thread support.

The names of the library files are constructed in the following way:

`thrh{`*`core`*`}{`*`code_model`*`}{`*`alignment`*`}{`*`size_of_double`*`}{`*`fpu`*`}{`*`lib_config`*`}.a`

which more specifically means

`thrh{3|4}n{4|8}{f|d}{|fpu32|fpu64}{n|f}.a`

Example: `thrh3n8dfpu32n.a`

Library files with support for timezone and daylight saving time functionality

These are the functions with support for timezone and daylight saving time functionality.

The names of the library files are constructed in the following way:

`tzrh{core}{code_model}{alignment}{size_of_double}{fpu}{lib_config}.a`

which more specifically means

`tzrh{3|4}n{4|8}{f|d}{|fpu32|fpu64}{n|f}.a`

Example: `tzrh3n8dfpu32n.a`

FORMATTERS FOR PRINTF

The `printf` function uses a formatter called `_Printf`. The full version is quite large, and provides facilities not required in many embedded applications. To reduce the memory consumption, three smaller, alternative versions are also provided. Note that the `wprintf` variants are not affected.

This table summarizes the capabilities of the different formatters:

Formatting capabilities	Tiny	Small/ SmallNoMb†	Large/ LargeNoMb†	Full/ FullNoMb†
Basic specifiers `c`, `d`, `i`, `o`, `p`, `s`, `u`, `X`, `x`, and `%`	Yes	Yes	Yes	Yes
Multibyte support	No	Yes/No	Yes/No	Yes/No
Floating-point specifiers `a`, and `A`	No	No	No	Yes
Floating-point specifiers `e`, `E`, `f`, `F`, `g`, and `G`	No	No	Yes	Yes
Conversion specifier `n`	No	No	Yes	Yes
Format flag `+`, `-`, `#`, `0`, and space	No	Yes	Yes	Yes
Length modifiers `h`, `l`, `L`, `s`, `t`, and `Z`	No	Yes	Yes	Yes
Field width and precision, including `*`	No	Yes	Yes	Yes
`long long` support	No	No	Yes	Yes
`wchar_t` support	No	No	No	Yes

Table 10: Formatters for printf

† `NoMb` means without multibytes.

The compiler can automatically detect which formatting capabilities are needed in a direct call to `printf`, if the formatting string is a string literal. This information is passed to the linker, which combines the information from all modules to select a suitable formatter for the application. However, if the formatting string is a variable, or if the call is indirect through a function pointer, the compiler cannot perform the analysis, forcing the linker to select the Full formatter. In this case, you might want to override the automatically selected `printf` formatter.

To override the automatically selected printf formatter in the IDE:

1. Choose **Project>Options>General Options** to open the **Options** dialog box.
2. On the **Library Options** page, select the appropriate formatter.

To override the automatically selected printf formatter from the command line:

1. Use one of these ILINK command line options:

```
--redirect __Printf=__PrintfFull
--redirect __Printf=__PrintfFullNoMb
--redirect __Printf=__PrintfLarge
--redirect __Printf=__PrintfLargeNoMb
--redirect __Printf=__PrintfSmall
--redirect __Printf=__PrintfSmallNoMb
--redirect __Printf=__PrintfTiny
--redirect __Printf=__PrintfTinyNoMb
```

If the compiler does not recognize multibyte support, you can enable it:

Select **Project>Options>General Options>Library Options 1>Enable multibyte support**.

Use the linker option `--printf_multibytes`.

FORMATTERS FOR SCANF

In a similar way to the `printf` function, `scanf` uses a common formatter, called `_Scanf`. The full version is quite large, and provides facilities that are not required in many embedded applications. To reduce the memory consumption, two smaller, alternative versions are also provided. Note that the `wscanf` versions are not affected.

This table summarizes the capabilities of the different formatters:

Formatting capabilities	Small/ SmallNoMb†	Large/ LargeNoMb†	Full/ FullNoMb†
Basic specifiers `c`, `d`, `i`, `o`, `p`, `s`, `u`, `X`, `x`, and `%`	Yes	Yes	Yes
Multibyte support	Yes/No	Yes/No	Yes/No
Floating-point specifiers `a`, and `A`	No	No	Yes
Floating-point specifiers `e`, `E`, `f`, `F`, `g`, and `G`	No	No	Yes
Conversion specifier `n`	No	No	Yes
Scan set `[` and `]`	No	Yes	Yes
Assignment suppressing `*`	No	Yes	Yes
`long long` support	No	No	Yes
`wchar_t` support	No	No	Yes

Table 11: Formatters for scanf

† `NoMb` means without multibytes.

The compiler can automatically detect which formatting capabilities are needed in a direct call to `scanf`, if the formatting string is a string literal. This information is passed to the linker, which combines the information from all modules to select a suitable formatter for the application. However, if the formatting string is a variable, or if the call is indirect through a function pointer, the compiler cannot perform the analysis, forcing the linker to select the full formatter. In this case, you might want to override the automatically selected `scanf` formatter.

To manually specify the scanf formatter in the IDE:

1. Choose **Project>Options>General Options** to open the **Options** dialog box.
2. On the **Library Options** page, select the appropriate formatter.

To manually specify the scanf formatter from the command line:

1. Use one of these ILINK command line options:

```
--redirect __Scanf=__ScanfFull
--redirect __Scanf=__ScanfFullNoMb
--redirect __Scanf=__ScanfLarge
--redirect __Scanf=__ScanfLargeNoMb
--redirect __Scanf=__ScanfSmall
--redirect __Scanf=__ScanfSmallNoMb
```

If the compiler does not recognize multibyte support, you can enable it:

Select **Project>Options>General Options>Library Options 1>Enable multibyte support**.

Use the linker option `--scanf_multibytes`.

THE C-SPY EMULATED I/O MECHANISM

The C-SPY emulated I/O mechanism works as follows:

1. The debugger will detect the presence of the function `__DebugBreak`, which will be part of the application if you linked it with the linker option for C-SPY emulated I/O.
2. In this case, the debugger will automatically set a breakpoint at the `__DebugBreak` function.
3. When your application calls a function in the DLIB low-level I/O interface, for example, `open`, the `__DebugBreak` function is called, which will cause the application to stop at the breakpoint and perform the necessary services.
4. The execution will then resume.

See also *Briefly about C-SPY emulated I/O*, page 126.

MATH FUNCTIONS

Some C/C++ standard library math functions are available in different versions:

- The default versions
- Smaller versions (but less accurate)
- More accurate versions (but larger).

Smaller versions

The functions `cos`, `exp`, `log`, `log2`, `log10`, `pow`, `sin`, and `tan` exist in additional, smaller versions in the library. They are about 20% smaller and about 20% faster than the default versions. The functions handle INF and NaN values. The drawbacks are that they almost always lose some precision and they do not have the same input range as the default versions.

The names of the functions are constructed like:

```
__iar_xxx_small<f|l>
```

where `f` is used for `float` variants, `l` is used for `long double` variants, and no suffix is used for `double` variants.

To specify which set of math functions to use:

1. Choose **Project>Options>General Options>Library Options 1>Math functions** and choose which set to use.
2. Link your application and the chosen set will be used.

To specify smaller math functions on the command line:

1. Specify the command line option `--small_math` to the linker.
2. Link your application and the complete set will be used.

More accurate versions

The functions `cos`, `pow`, `sin`, and `tan` exist in versions in the library that are more exact and can handle larger argument ranges. The drawback is that they are larger and slower than the default versions.

The names of the functions are constructed like:

```
__iar_xxx_accurate<f|l>
```

where `f` is used for `float` variants, `l` is used for `long double` variants, and no suffix is used for `double` variants.

To specify more accurate math functions on the command line:

1. Specify the command line option `--accurate_math` to the linker.
2. Link your application and the complete set will be used.

SYSTEM STARTUP AND TERMINATION

This section describes the runtime environment actions performed during startup and termination of your application.

The code for handling startup and termination is located in the source files cstartup and `low_level_init.c` located in the `rh850\src\lib` directory. The name of the cstartup file depends on the device you are developing for:

Type of RH850 device	Cstartup filename
G3 Single-core	`cstartup.s`
G3 Multi-core	`cstartup`*n*`.s`
G3 with a PCU core	`cstartup`*n*`_pcu.s`
G4 Single-core	`cstartup_g4.s`
G4 Multi-core	`cstartup`*n*`_g4.s`

Table 12: Naming convention for the cstartup file

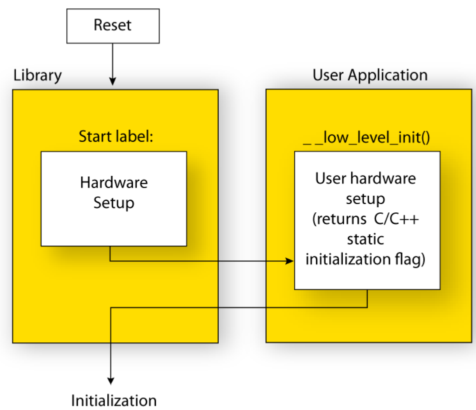
n corresponds to the number of cores that your application uses.

For information about how to customize the system startup code, see *System initialization*, page 146.

System startup

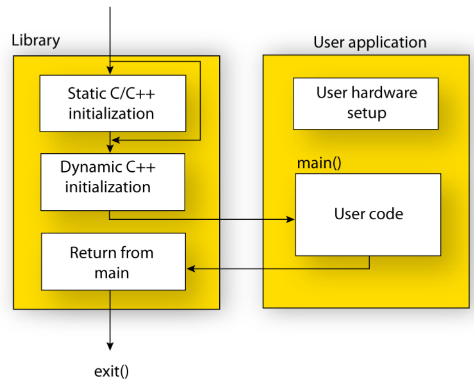
During system startup, an initialization sequence is executed before the `main` function is entered. This sequence performs initializations required for the target hardware and the C/C++ environment.

For the hardware initialization, it looks like this:



- When the CPU is reset it will start executing at the program entry label in the system startup code (see *Building applications—an overview*, page 63, for a description of the program start label).
- The stack pointer is initialized to the end of the `CSTACK` block
- The function `__low_level_init` is called if you defined it, giving the application a chance to perform early initializations.

For the C/C++ initialization, it looks like this:

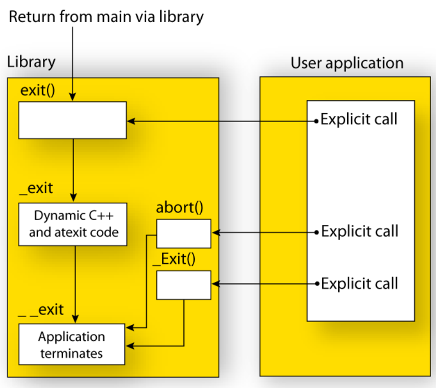


- Static and global variables are initialized. That is, zero-initialized variables are cleared and the values of other initialized variables are copied from ROM to RAM memory. This step is skipped if `__low_level_init` returns zero. For more information, see *Initialization at system startup*, page 96.
- Static C++ objects are constructed
- The `main` function is called, which starts the application.

For information about the initialization phase, see *Application execution—an overview*, page 58.

System termination

This illustration shows the different ways an embedded application can terminate in a controlled way:



An application can terminate normally in two different ways:

- Return from the `main` function
- Call the `exit` function.

Because the C standard states that the two methods should be equivalent, the system startup code calls the `exit` function if `main` returns. The parameter passed to the `exit` function is the return value of `main`.

The default `exit` function is written in C. It calls a small assembler function `_exit` that will:

- Call functions registered to be executed when the application ends. This includes C++ destructors for static and global variables, and functions registered with the standard function `atexit`. See also *Setting up the atexit limit*, page 112.
- Close all open files
- Call `__exit`
- When `__exit` is reached, stop the system.

An application can also exit by calling the `abort`, the `_Exit`, or the `quick_exit` function. The `abort` function just calls `__exit` to halt the system, and does not perform any type of cleanup. The `_Exit` function is equivalent to the `abort` function, except for the fact that `_Exit` takes an argument for passing exit status information. The `quick_exit` function is equivalent to the `_Exit` function, except that it calls each function passed to `at_quick_exit` before calling `__exit`.

If you want your application to do anything extra at exit, for example, resetting the system (and if using `atexit` is not sufficient), you can write your own implementation of the `__exit(int)` function.

The library files that you can override with your own versions are located in the `rh850\src\lib` directory. See *Overriding library modules*, page 131.

C-SPY debugging support for system termination

If you have enabled C-SPY emulated I/O during linking, the normal `__exit` and `abort` functions are replaced with special ones. C-SPY will then recognize when those functions are called and can take appropriate actions to emulate program termination. For more information, see *Briefly about C-SPY emulated I/O*, page 126.

SYSTEM INITIALIZATION

It is likely that you need to adapt the system initialization. For example, your application might need to initialize memory-mapped special function registers (SFRs), or omit the default initialization of data sections performed by the system startup code.

You can do this by implementing your own version of the routine `__low_level_init`, which is called from the cstartup file before the data sections are initialized. Modifying the cstartup file directly should be avoided.

The code for handling system startup is located in the source files cstartup and `low_level_init.c`, located in the `rh850\src\lib` directory. For the name of the cstartup file, see *System startup and termination*, page 142.

Note that normally, you do not need to customize `cexit.s`.

Note: Regardless of whether you implement your own version of `__low_level_init` or the file cstartup, you do not have to rebuild the library.

For information about how this works for multicore devices, see *Adapting the system initialization for multiple cores*, page 207.

Customizing __low_level_init

Two skeleton low-level initialization files are supplied with the product: a C source file, `low_level_init.c` and an alternative assembler source file, `low_level_init.s`. The latter is part of the prebuilt runtime environment. The only limitation using the C source version is that static initialized variables cannot be used within the file, as variable initialization has not been performed at this point.

The value returned by `__low_level_init` determines whether or not data sections should be initialized by the system startup code. If the function returns `0`, the data sections will not be initialized.

The `__low_level_init` function has an integer input parameter that identifies the calling core. The permitted range is 1–7.

Modifying the cstartup file

As noted earlier, you should not modify the cstartup file if implementing your own version of `__low_level_init` is enough for your needs. However, if you do need to modify the cstartup file, we recommend that you follow the general procedure for creating a modified copy of the file and adding it to your project, see *Overriding library modules*, page 131.

Note: You must make sure that the linker uses the start label used in your version of `cstartup.s`. For information about how to change the start label used by the linker, see *--entry*, page 306.

THE DLIB LOW-LEVEL I/O INTERFACE

The runtime library uses a set of low-level functions—which are referred to as the *DLIB low-level I/O interface*—to communicate with the target system. Most of the low-level functions have no implementation.

For more information, see *Briefly about input and output (I/O)*, page 124.

These are the functions in the DLIB low-level I/O interface:

```
abort
clock
__close
__exit
getenv
__getzone
__iar_ReportAssert
__lseek
__open
raise
__read
remove
rename
```

signal

system

__time32, __time64

__write

Note: You should normally not use the low-level functions prefixed with __ directly in your application. Instead you should use the standard library functions that use these functions. For example, to write to `stdout`, you should use standard library functions like `printf` or `puts`, which in turn calls the low-level function `__write`. If you have forgot to implement a low-level function and your application calls that function via a standard library function, the linker issues an error when you link in release build configuration.

Note: If you implement your own variants of the functions in this interface, your variants will be used even though you have enabled C-SPY emulated I/O, see *Briefly about C-SPY emulated I/O*, page 126.

abort

Source file `rh850\src\lib\runtime\abort.c`

Declared in `stdlib.h`

Description Standard C library function that aborts execution.

C-SPY debug action Notifies that the application has called abort.

Exits the application.

Default implementation Calls `__exit(EXIT_FAILURE)`.

See also *Briefly about retargeting*, page 126

System termination, page 145.

clock

Source file `rh850\src\lib\time\clock.c`

Declared in `time.h`

Description	Standard C library function that accesses the processor time.
C-SPY debug action	Returns the clock on the host computer.
Default implementation	Returns `-1` to indicate that processor time is not available.
See also	*Briefly about retargeting*, page 126.

__close

Source file	`rh850\src\lib\file\close.c`
Declared in	`LowLevelIOInterface.h`
Description	Low-level function that closes a file.
C-SPY debug action	Closes the associated host file on the host computer.
Default implementation	None.
See also	*Briefly about retargeting*, page 126.

__exit

Source file	`rh850\src\lib\runtime\xxexit.c`
Declared in	`LowLevelIOInterface.h`
Description	Low-level function that halts execution.
C-SPY debug action	Notifies that the end of the application was reached.
Default implementation	Loops forever.
See also	*Briefly about retargeting*, page 126 *System termination*, page 145.

getenv

Source file rh850\src\lib\runtime\getenv.c
rh850\src\lib\runtime\environ.c

Declared in Stdlib.h and LowLevelIOInterface.h

C-SPY debug action Accesses the host environment.

Default implementation The getenv function in the library searches the string pointed to by the global variable __environ, for the key that was passed as argument. If the key is found, the value of it is returned, otherwise 0 (zero) is returned. By default, the string is empty.

To create or edit keys in the string, you must create a sequence of null-terminated strings where each string has the format:

```
key=value\0
```

End the string with an extra null character (if you use a C string, this is added automatically). Assign the created sequence of strings to the __environ variable.

For example:

```
const char MyEnv[] = "Key=Value\0Key2=Value2\0";
__environ = MyEnv;
```

If you need a more sophisticated environment variable handling, you should implement your own getenv, and possibly putenv function.

Note: The putenv function is not required by the standard, and the library does not provide an implementation of it.

See also *Briefly about retargeting*, page 126.

__getzone

Source file rh850\src\lib\time\getzone.c

Declared in LowLevelIOInterface.h

Description Low-level function that returns the current time zone.

Note: You must enable the time zone functionality in the library by using the linker option --timezone_lib.

C-SPY debug action Not applicable.

Default implementation — Returns `":"`.

See also — *Briefly about retargeting*, page 126 and --*timezone_lib*, page 323.

For more information, see the source file `getzone.c`.

__iar_ReportAssert

Source file — `rh850\src\lib\runtime\xreportassert.c`

Declared in — `assert.h`

Description — Low-level function that handles a failed assert.

C-SPY debug action — Notifies the C-SPY debugger about the failed assert.

Default implementation — Failed asserts are reported by the function `__iar_ReportAssert`. By default, it prints an error message and calls `abort`. If this is not the behavior you require, you can implement your own version of the function.

The assert macro is defined in the header file `assert.h`. To turn off assertions, define the symbol `NDEBUG`.

In the IDE, the symbol `NDEBUG` is by default defined in a Release project and *not* defined in a Debug project. If you build from the command line, you must explicitly define the symbol according to your needs. See *NDEBUG*, page 409.

See also — *Briefly about retargeting*, page 126.

__lseek

Source file — `rh850\src\lib\file\lseek.c`

Declared in — `LowLevelIOInterface.h`

Description — Low-level function for changing the location of the next access in an open file.

C-SPY debug action — Searches in the associated host file on the host computer.

Default implementation — None.

See also — *Briefly about retargeting*, page 126.

__open

Source file	`rh850\src\lib\file\open.c`
Declared in	`LowLevelIOInterface.h`
Description	Low-level function that opens a file.
C-SPY debug action	Opens a file on the host computer.
Default implementation	None.
See also	*Briefly about retargeting*, page 126.

raise

Source file	`rh850\src\lib\runtime\raise.c`
Declared in	`signal.h`
Description	Standard C library function that raises a signal.
C-SPY debug action	Not applicable.
Default implementation	Calls the signal handler for the raised signal, or terminates with call to `__exit(EXIT_FAILURE)`.
See also	*Briefly about retargeting*, page 126.

__read

Source file	`rh850\src\lib\file\read.c`
Declared in	`LowLevelIOInterface.h`
Description	Low-level function that reads characters from `stdin` and from files.
C-SPY debug action	Directs `stdin` to the **Terminal I/O** window. All other files will read the associated host file.
Default implementation	None.

Example

The code in this example uses memory-mapped I/O to read from a keyboard, whose port is assumed to be located at `0x8`:

```
#include <stddef.h>

__no_init volatile unsigned char kbIO @ 8;

size_t __read(int handle,
              unsigned char *buf,
              size_t bufSize)
{
  size_t nChars = 0;

  /* Check for stdin
     (only necessary if FILE descriptors are enabled) */
  if (handle != 0)
  {
    return -1;
  }

  for (/*Empty*/; bufSize > 0; --bufSize)
  {
    unsigned char c = kbIO;
    if (c == 0)
      break;

    *buf++ = c;
    ++nChars;
  }

  return nChars;
}
```

For information about the handles associated with the streams, see *Retargeting—Adapting for your target system*, page 129.

For information about the `@` operator, see *Controlling data and function placement in memory*, page 224.

See also

Briefly about retargeting, page 126.

remove

Source file

`rh850\src\lib\file\remove.c`

Declared in

`stdio.h`

Description	Standard C library function that removes a file.
C-SPY debug action	Writes a message to the **Debug Log** window and returns `-1`.
Default implementation	Returns `0` to indicate success, but without removing a file.
See also	*Briefly about retargeting*, page 126.

rename

Source file	`rh850\src\lib\file\rename.c`
Declared in	`stdio.h`
Description	Standard C library function that renames a file.
C-SPY debug action	None.
Default implementation	Returns `-1` to indicate failure.
See also	*Briefly about retargeting*, page 126.

signal

Source file	`rh850\src\lib\runtime\signal.c`
Declared in	`signal.h`
Description	Standard C library function that changes signal handlers.
C-SPY debug action	Not applicable.
Default implementation	As specified by Standard C. You might want to modify this behavior if the environment supports some kind of asynchronous signals.
See also	*Briefly about retargeting*, page 126.

system

Source file
`rh850\src\lib\runtime\system.c`

Declared in
`stdlib.h`

Description
Standard C library function that executes commands.

C-SPY debug action
Notifies the C-SPY debugger that `system` has been called and then returns `-1`.

Default implementation
The `system` function available in the library returns `0` if a null pointer is passed to it to indicate that there is no command processor, otherwise it returns `-1` to indicate failure. If this is not the functionality that you require, you can implement your own version. This does not require that you rebuild the library.

See also
Briefly about retargeting, page 126.

__time32, __time64

Source file
`rh850\src\lib\time\time.c`
`rh850\src\lib\time\time64.c`

Declared in
`time.h`

Description
Low-level functions that return the current calendar time.

C-SPY debug action
Returns the time on the host computer.

Default implementation
Returns `-1` to indicate that calendar time is not available.

See also
Briefly about retargeting, page 126.

__write

Source file
`rh850\src\lib\file\write.c`

Declared in
`LowLevelIOInterface.h`

Description
Low-level function that writes to `stdout`, `stderr`, or a file.

C-SPY debug action
Directs `stdout` and `stderr` to the **Terminal I/O** window. All other files will write to the associated host file.

Default implementation

None.

Example

The code in this example uses memory-mapped I/O to write to an LCD display, whose port is assumed to be located at address `0x8`:

```
#include <stddef.h>

__no_init volatile unsigned char lcdIO @ 8;

size_t __write(int handle,
               const unsigned char *buf,
               size_t bufSize)
{
  size_t nChars = 0;

  /* Check for the command to flush all handles */
  if (handle == -1)
  {
    return 0;
  }

  /* Check for stdout and stderr
     (only necessary if FILE descriptors are enabled.) */
  if (handle != 1 && handle != 2)
  {
    return -1;
  }

  for (/* Empty */; bufSize > 0; --bufSize)
  {
    lcdIO = *buf;
    ++buf;
    ++nChars;
  }

  return nChars;
}
```

For information about the handles associated with the streams, see *Retargeting—Adapting for your target system*, page 129.

See also

Briefly about retargeting, page 126.

CONFIGURATION SYMBOLS FOR FILE INPUT AND OUTPUT

File I/O is only supported by libraries with the Full library configuration, see *Runtime library configurations*, page 134, or in a customized library when the configuration symbol `__DLIB_FILE_DESCRIPTOR` is defined. If this symbol is not defined, functions taking a `FILE *` argument cannot be used.

To customize your library and rebuild it, see *Customizing and building your own runtime library*, page 132.

LOCALE

Locale is a part of the C language that allows language and country-specific settings for several areas, such as currency symbols, date and time, and multibyte character encoding.

Depending on which library configuration you are using, you get different levels of locale support. However, the more locale support, the larger your code will get. It is therefore necessary to consider what level of support your application needs. See *Runtime library configurations*, page 134.

The DLIB runtime library can be used in two main modes:

- Using a full library configuration that has a locale interface, which makes it possible to switch between different locales during runtime

  The application starts with the C locale. To use another locale, you must call the `setlocale` function or use the corresponding mechanisms in C++. The locales that the application can use are set up at linkage.
- Using a normal library configuration that does not have a locale interface, where the C locale is hardwired into the application.

Note: If multibytes are to be printed, you must make sure that the implementation of `__write` in the DLIB low-level I/O interface can handle them.

Specifying which locales that should be available in your application

Choose **Project>Options>General Options>Library Options 2>Locale support**.

Use the linker option `--keep` with the tag of the locale as the parameter, for example:

```
--keep _Locale_cs_CZ_iso8859_2
```

The available locales are listed in the file `SupportedLocales.json` in the `rh850\config` directory, for example:

```
['Czech language locale for Czech Republic', 'iso8859-2',
'cs_CZ.iso8859-2', '_Locale_cs_CZ_iso8859_2'],
```

The line contains the full locale name, the encoding for the locale, the abbreviated locale name, and the tag to be used as parameter to the linker option `--keep`.

Changing locales at runtime

The standard library function `setlocale` is used for selecting the appropriate portion of the application's locale when the application is running.

The `setlocale` function takes two arguments. The first one is a locale category that is constructed after the pattern `LC_`*`CATEGORY`*. The second argument is a string that describes the locale. It can either be a string previously returned by `setlocale`, or it can be a string constructed after the pattern:

`lang_REGION`

or

`lang_REGION.encoding`

The *`lang`* part specifies the language code, and the *`REGION`* part specifies a region qualifier, and *`encoding`* specifies the multibyte character encoding that should be used. The available encodings are ISO-8859-1, ISO-8859-2, ISO-8859-4, ISO-8859-5, ISO-8859-7, ISO-8859-8, ISO-8859-9, ISO-8859-15, CP932, and UTF-8.

For a complete list of the available locales and their respective encoding, see the file `SupportedLocales.json` in the `rh850\config` directory.

Example

This example sets the locale configuration symbols to Swedish to be used in Finland and `UTF8` multibyte character encoding:

```
setlocale (LC_ALL, "sv_FI.UTF8");
```

STRTOD

The function `strtod` does not accept hexadecimal floating-point strings in libraries with the normal library configuration. To make `strtod` accept hexadecimal floating-point strings, you must:

1. Enable the configuration symbol `_DLIB_STRTOD_HEX_FLOAT` in the library configuration file.
2. Rebuild the library, see *Customizing and building your own runtime library*, page 132.

Managing a multithreaded environment

This section contains information about:

- *Multithread support in the DLIB runtime environment*, page 159
- *Enabling multithread support*, page 160

In a multithreaded environment, the standard library must treat all library objects according to whether they are global or local to a thread. If an object is a true global object, any updates of its state must be guarded by a locking mechanism to make sure that only one thread can update it at any given time. If an object is local to a thread, the static variables containing the object state must reside in a variable area local to that thread. This area is commonly named *thread-local storage* (TLS).

The low-level implementations of locks and TLS are system-specific, and is not included in the DLIB runtime environment. If you are using an RTOS, check if it provides some or all of the required functions. Otherwise, you must provide your own.

MULTITHREAD SUPPORT IN THE DLIB RUNTIME ENVIRONMENT

The DLIB runtime environment uses two kinds of locks—*system locks* and *file stream locks*. The file stream locks are used as guards when the state of a file stream is updated, and are only needed in the Full library configuration. The following objects are guarded with system locks:

- The heap (in other words when `malloc`, `new`, `free`, `delete`, `realloc`, or `calloc` is used).
- The C file system (only available in the Full library configuration), but not the file streams themselves. The file system is updated when a stream is opened or closed, in other words when `fopen`, `fclose`, `fdopen`, `fflush`, or `freopen` is used.
- The signal system (in other words when `signal` is used).
- The temporary file system (in other words when `tmpnam` is used).
- C++ dynamically initialized function-local objects with static storage duration.
- C++ locale facet handling
- C++ regular expression handling
- C++ terminate and unexpected handling

These library objects use TLS:

Library objects using TLS	When these functions are used
Error functions	`errno`, `strerror`

Table 13: Library objects using TLS

Note: If you are using `printf`/`scanf` (or any variants) with formatters, each individual formatter will be guarded, but the complete `printf`/`scanf` invocation will not be guarded.

If C++ is used in a runtime environment with multithread support, the compiler option `--guard_calls` must be used to make sure that function-static variables with dynamic initializers are not initialized simultaneously by several threads.

ENABLING MULTITHREAD SUPPORT

To configure multithread support for use with threaded applications:

1 To enable multithread support:

On the command line, use the linker option `--threaded_lib`.

If C++ is used, the compiler option `--guard_calls` should be used as well to make sure that function-static variables with dynamic initializers are not initialized simultaneously by several threads.

In the IDE, choose **Project>Options>General Options>Library Configuration>Enable thread support in the library**. This will invoke the linker option `--threaded_lib` and if C++ is used, the IDE will automatically use the compiler option `--guard_calls` to make sure that function-static variables with dynamic initializers are not initialized simultaneously by several threads.

2 To complement the built-in multithread support in the runtime library, you must also:

- Implement code for the library's system locks interface.
- If file streams are used, implement code for the library's file stream locks interface.
- Implement code that handles thread creation, thread destruction, and TLS access methods for the library.

You can find the required declaration of functions in the `DLib_Threads.h` file. There you will also find more information.

3 Build your project.

Note: If you are using a third-party RTOS, check their guidelines for how to enable multithread support with IAR Systems tools.

Assembler language interface

- Mixing C and assembler
- Calling assembler routines from C
- Calling assembler routines from C++
- Calling convention
- Assembler instructions used for calling functions
- Memory access methods
- Call frame information

Mixing C and assembler

The IAR C/C++ Compiler for RH850 provides several ways to access low-level resources:

- Modules written entirely in assembler
- Intrinsic functions (the C alternative)
- Inline assembler.

It might be tempting to use simple inline assembler. However, you should carefully choose which method to use.

INTRINSIC FUNCTIONS

The compiler provides a few predefined functions that allow direct access to low-level processor operations without having to use the assembler language. These functions are known as intrinsic functions. They can be useful in, for example, time-critical routines.

An intrinsic function looks like a normal function call, but it is really a built-in function that the compiler recognizes. The intrinsic functions compile into inline code, either as a single instruction, or as a short sequence of instructions.

For more information about the available intrinsic functions, see the chapter *Intrinsic functions*.

MIXING C AND ASSEMBLER MODULES

It is possible to write parts of your application in assembler and mix them with your C or C++ modules.

When an application is written partly in assembler language and partly in C or C++, you are faced with several questions:

- How should the assembler code be written so that it can be called from C?
- Where does the assembler code find its parameters, and how is the return value passed back to the caller?
- How should assembler code call functions written in C?
- How are global C variables accessed from code written in assembler language?
- Why does not the debugger display the call stack when assembler code is being debugged?

The first question is discussed in the section *Calling assembler routines from C*, page 168. The following two are covered in the section *Calling convention*, page 171.

For information about how data in memory is accessed, see *Memory access methods*, page 178.

The answer to the final question is that the call stack can be displayed when you run assembler code in the debugger. However, the debugger requires information about the call frame, which must be supplied as annotations in the assembler source file. For more information, see *Call frame information*, page 182.

The recommended method for mixing C or C++ and assembler modules is described in *Calling assembler routines from C*, page 168, and *Calling assembler routines from C++*, page 170, respectively.

Note: To comply with the Renesas ABI, the compiler generates assembler labels for symbol and function names by prefixing an underscore. You must remember to add this extra underscore when you access C symbols from assembler. For example, `main` must be written as `_main`.

Similarly, when referencing an external assembly module from C, an underscore will be added to the symbol used in the C module, so the name of the assembly module must start with an added underscore.

INLINE ASSEMBLER

Inline assembler can be used for inserting assembler instructions directly into a C or C++ function. Typically, this can be useful if you need to:

- Access hardware resources that are not accessible in C (in other words, when there is no definition for an SFR or there is no suitable intrinsic function available).

- Manually write a time-critical sequence of code that if written in C will not have the right timing.
- Manually write a speed-critical sequence of code that if written in C will be too slow.

An inline assembler statement is similar to a C function in that it can take input arguments (input operands), have return values (output operands), and read or write to C symbols (via the operands). An inline assembler statement can also declare *clobbered resources* (that is, values in registers and memory that have been overwritten).

Limitations

Most things you can to do in normal assembler language are also possible with inline assembler, with the following differences:

- Alignment cannot be controlled; this means, for example, that `DC32` directives might be misaligned.
- In general, assembler directives will cause errors or have no meaning. However, data definition directives will work as expected.
- Resources used (registers, memory, etc) that are also used by the C compiler must be declared as operands or clobbered resources.
- If you do not want to risk that the inline assembler statement to be optimized away by the compiler, you must declare it `volatile`.
- Accessing a C symbol or using a constant expression requires the use of operands.
- Dependencies between the expressions for the operands might result in an error.

Risks with inline assembler

Without operands and clobbered resources, inline assembler statements have no interface with the surrounding C source code. This makes the inline assembler code fragile, and might also become a maintenance problem if you update the compiler in the future. There are also several limitations to using inline assembler without operands and clobbered resources:

- The compiler's various optimizations will disregard any effects of the inline statements, which will not be optimized at all.
- The inline assembler statement will be `volatile` and *clobbered memory* is not implied. This means that the compiler will not remove the assembler statement. It will simply be inserted at the given location in the program flow. The consequences or side-effects that the insertion might have on the surrounding code are not taken into consideration. If, for example, registers or memory locations are altered, they might have to be restored within the sequence of inline assembler instructions for the rest of the code to work properly.

The following example demonstrates the risks of using the `asm` keyword without operands and clobbers:

```
int Add(int term1, int term2)
{
  asm("add r7,r6");
  return term1;
}
```

In this example:

- The function `Add` assumes that values are passed and returned in registers in a way that they might not always be, for example if the function is inlined.
- The `add` instruction updates the condition flags, which should be specified using the `cc` clobber operand. Otherwise, the compiler will assume that the condition flags are not modified.

Inline assembler without using operands or clobbered resources is therefore often best avoided.

Reference information for inline assembler

The `asm` and `__asm` keywords both insert inline assembler instructions. However, when you compile C source code, the `asm` keyword is not available when the option `--strict` is used. The `__asm` keyword is always available.

Syntax

The syntax of an inline assembler statement is (similar to the one used by GNU gcc):

```
asm [volatile]( string [assembler-interface])
```

`string` can contain one or more valid assembler instructions or data definition assembler directives, separated by `\n`. `string` cannot contain a comment.

For example:

```
asm("label:nop\n"
    "jr label");
```

Note that you can define and use local labels in inline assembler instructions.

`assembler-interface` is:

```
  : comma-separated list of output operands     /* optional */
  : comma-separated list of input operands      /* optional */
  : comma-separated list of clobbered resources /* optional */
```

Operands

An inline assembler statement can have one input and one output comma-separated list of operands. Each operand consists of an optional symbolic name in brackets, a quoted constraint, followed by a C expression in parentheses.

Syntax of operands

`[[ symbolic-name ]] "[modifiers]constraint" (expr)`

For example:

```
int Add(int term1, int term2)
{
  int sum;

  asm("mov %1,%0\n"
      "add %2,%0"
      : "=r"(sum)
      : "r" (term1), "r" (term2));

  return sum;
}
```

In this example, the assembler instruction uses one output operand, `sum`, two input operands, `term1` and `term2`, and no clobbered resources.

It is possible to omit any list by leaving it empty. For example:

```
int matrix[M][N];

void MatrixPreloadRow(int row)
{
  asm volatile ("pref 4,[%0]" : : "r" (&matrix[row][0]));
}
```

Operand constraints

Constraint	Description
`r`	Uses a general purpose register for the expression: `R1`, `R6-R31`
`l`	An immediate integer operand (an operand with a constant value) is allowed. This includes symbolic constants whose values will be known only at assembly time or later.

Table 14: Inline assembler operand constraints

Constraint modifiers

Constraint modifiers can be used together with a constraint to modify its meaning. This table lists the supported constraint modifiers:

Modifier	Desciption
=	Write-only operand

Table 15: Supported constraint modifiers

Modifier	Desciption
+	Read-write operand
&	Early clobber output operand which is written to before the instruction has processed all the input operands.

Table 15: Supported constraint modifiers (Continued)

Referring to operands

Assembler instructions refer to operands by prefixing their order number with `%`. The first operand has order number `0` and is referred to by `%0`.

If the operand has a symbolic name, you can refer to it using the syntax `%[`*`operand.name`*`]`. Symbolic operand names are in a separate namespace from C/C++ code and can be the same as a C/C++ variable names. Each operand name must however be unique in each assembler statement. For example:

```
int Add(int term1, int term2)
{
  int sum;

  asm("mov %[Rm],%[Rd]\n"
      "add %[Rn],%[Rd]"
      : [Rd]"=r"(sum)
      : [Rn]"r" (term1), [Rm]"r" (term2));

  return sum;
}
```

Input operands

Input operands cannot have any modifiers, but they can have any valid C expression as long as the type of the expression fits the register.

The C expression will be evaluated just before any of the assembler instructions in the inline assembler statement and assigned to the constraint, for example a register.

Output operands

Output operands must have `=` as a modifier and the C expression must be an l-value and specify a writable location. For example, `=r` for a write-only general purpose register. The constraint will be assigned to the evaluated C expression (as an l-value) immediately after the last assembler instruction in the inline assembler statement. Input operands are assumed to be consumed before output is produced and the compiler may use the same register for an input and output operand. To prohibit this, prefix the output constraint with `&` to make it an early clobber resource, for example `=&r`. This will ensure that the output operand will be allocated in a different register than the input operands.

Input/output operands

An operand that should be used both for input and output must be listed as an output operand and have the `+` modifier. The C expression must be an l-value and specify a writable location. The location will be read immediately before any assembler instructions and it will be written to right after the last assembler instruction.

This is an example of using a read-write operand:

```
int Double(int value)
{
  asm("add %0,%0" : "+r"(value));

  return value;
}
```

In the example above, the input value for `value` will be placed in a general purpose register. After the assembler statement, the result from the `ADD` instruction will be placed in the same register.

Clobbered resources

An inline assembler statement can have a list of clobbered resources.

"*resource1*", "*resource2*", ...

Specify clobbered resources to inform the compiler about which resources the inline assembler statement destroys. Any value that resides in a clobbered resource and that is needed after the inline assembler statement will be reloaded.

Clobbered resources will not be used as input or output operands.

This is an example of how to use clobbered resources:

```
int Add(int term1, int term2)
{
  int sum;

  asm("mov %1,%0\n"
      "add %2,%0"
      : "=r"(sum)
      : "r" (term1), "r" (term2)
      : "cc");

  return sum;
}
```

In this example the condition codes will be modified by the `ADD` instruction. Therefore, `"cc"` must be listed in the clobber list.

This table lists valid clobbered resources:

Clobber	Description
R1, R6-R31	General purpose registers. Note that registers that have been locked with one of the options --lock_10_regs or --lock_global_pointer_regs are not valid clobbered registers.
cc	The condition flags (CY, Z, S, OV, and SAT)
memory	To be used if the instructions modify any memory. This will avoid keeping memory values cached in registers across the inline assembler statement.

Table 16: List of valid clobbers

AN EXAMPLE OF HOW TO USE CLOBBERED MEMORY

```
int StoreExclusive(unsigned long * location, unsigned long value)
{
  asm("stc.w %0,[%1]"
      : "+r"(value)
      : "r"(location)
      : "memory");

  return value;
}
```

Calling assembler routines from C

An assembler routine that will be called from C must:

- Conform to the calling convention
- Have a PUBLIC entry-point label
- Be declared as external before any call, to allow type checking and optional promotion of parameters, as in these examples:

  ```
  extern int foo(void);
  ```

  or

  ```
  extern int foo(int i, int j);
  ```

One way of fulfilling these requirements is to create skeleton code in C, compile it, and study the assembler list file.

CREATING SKELETON CODE

The recommended way to create an assembler language routine with the correct interface is to start with an assembler language source file created by the C compiler.

Note: You must create skeleton code for each function prototype.

The following example shows how to create skeleton code to which you can easily add the functional body of the routine. The skeleton source code only needs to declare the variables required and perform simple accesses to them. In this example, the assembler routine takes an `int` and a `char`, and then returns an `int`:

```
extern int gInt;
extern char gChar;

int Func(int arg1, char arg2)
{
  int locInt = arg1;
  gInt = arg1;
  gChar = arg2;
  return locInt;
}

int main()
{
  int locInt = gInt;
  gInt = Func(locInt, gChar);
  return 0;
}
```

Note: In this example, we use a low optimization level when compiling the code to show local and global variable access. If a higher level of optimization is used, the required references to local variables could be removed during the optimization. The actual function declaration is not changed by the optimization level.

COMPILING THE SKELETON CODE

In the IDE, specify list options on file level. Select the file in the workspace window. Then choose **Project>Options**. In the **C/C++ Compiler** category, select **Override inherited settings**. On the **List** page, deselect **Output list file**, and instead select the **Output assembler file** option and its suboption **Include source**. Also, be sure to specify a low level of optimization.

Use these options to compile the skeleton code:

```
iccrh850 skeleton.c -lA . -On -e
```

The `-lA` option creates an assembler language output file including C or C++ source lines as assembler comments. The `.` (period) specifies that the assembler file should be named in the same way as the C or C++ module (`skeleton`), but with the filename extension `s`. The `-On` option means that no optimization will be used and `-e` enables language extensions. In addition, make sure to use relevant compiler options, usually the same as you use for other C or C++ source files in your project.

The result is the assembler source output file `skeleton.s`.

Note: The `-lA` option creates a list file containing call frame information (`CFI`) directives, which can be useful if you intend to study these directives and how they are used. If you only want to study the calling convention, you can exclude the `CFI` directives from the list file.

In the IDE, to exclude the `CFI` directives from the list file, choose **Project>Options>C/C++ Compiler>List** and deselect the suboption **Include call frame information**.

On the command line, to exclude the `CFI` directives from the list file, use the option `-lB` instead of `-lA`.

Note: `CFI` information must be included in the source code to make the C-SPY **Call Stack** window work.

The output file

The output file contains the following important information:

- The calling convention
- The return values
- The global variables
- The function parameters
- How to create space on the stack (auto variables)
- Call frame information (CFI).

The `CFI` directives describe the call frame information needed by the **Call Stack** window in the debugger. For more information, see *Call frame information*, page 182.

Calling assembler routines from C++

The C calling convention does not apply to C++ functions. Most importantly, a function name is not sufficient to identify a C++ function. The scope and the type of the function are also required to guarantee type-safe linkage, and to resolve overloading.

Another difference is that non-static member functions get an extra, hidden argument, the `this` pointer.

However, when using C linkage, the calling convention conforms to the C calling convention. An assembler routine can therefore be called from C++ when declared in this manner:

```
extern "C"
{
  int MyRoutine(int);
}
```

In C++, data structures that only use C features are known as PODs (“plain old data structures”), they use the same memory layout as in C. However, we do not recommend that you access non-PODs from assembler routines.

The following example shows how to achieve the equivalent to a non-static member function, which means that the implicit `this` pointer must be made explicit. It is also possible to “wrap” the call to the assembler routine in a member function. Use an inline member function to remove the overhead of the extra call—this assumes that function inlining is enabled:

```
class MyClass;

extern "C"
{
  void DoIt(MyClass *ptr, int arg);
}

class MyClass
{
public:
  inline void DoIt(int arg)
  {
    ::DoIt(this, arg);
  }
};
```

Calling convention

A calling convention is the way a function in a program calls another function. The compiler handles this automatically, but, if a function is written in assembler language, you must know where and how its parameters can be found, how to return to the program location from where it was called, and how to return the resulting value.

It is also important to know which registers an assembler-level routine must preserve. If the program preserves too many registers, the program might be ineffective. If it preserves too few registers, the result would be an incorrect program.

This section describes the calling convention used by the compiler. These items are examined:

- Function declarations
- C and C++ linkage
- Preserved versus scratch registers
- Function entrance
- Function exit
- Return address handling

At the end of the section, some examples are shown to describe the calling convention in practice.

FUNCTION DECLARATIONS

In C, a function must be declared in order for the compiler to know how to call it. A declaration could look as follows:

```
int MyFunction(int first, char * second);
```

This means that the function takes two parameters: an integer and a pointer to a character. The function returns a value, an integer.

In the general case, this is the only knowledge that the compiler has about a function. Therefore, it must be able to deduce the calling convention from this information.

USING C LINKAGE IN C++ SOURCE CODE

In C++, a function can have either C or C++ linkage. To call assembler routines from C++, it is easiest if you make the C++ function have C linkage.

This is an example of a declaration of a function with C linkage:

```
extern "C"
{
  int F(int);
}
```

It is often practical to share header files between C and C++. This is an example of a declaration that declares a function with C linkage in both C and C++:

```
#ifdef __cplusplus
extern "C"
{
#endif

int F(int);

#ifdef __cplusplus
}
#endif
```

PRESERVED VERSUS SCRATCH REGISTERS

The general RH850 CPU registers are divided into three separate sets, which are described in this section.

Scratch registers

Any function is permitted to destroy the contents of a scratch register. If a function needs the register value after a call to another function, it must store it during the call, for example on the stack.

Any of the registers `R1` and `R6–R19`, and the return address registers, can be used as a scratch register by the function. (The registers `R15–R19` are not available if they have been locked with the `--lock_10_regs` option.)

Preserved registers

Preserved registers, on the other hand, are preserved across function calls. The called function can use the register for other purposes, but must save the value before using the register and restore it at the exit of the function.

The registers `R20–R29` (and `R30` if the `EP` is not used for short addressing), but not including the return address registers, are preserved registers. Note that registers `R20–R24` are not available if one of the options `--lock_10_regs` or `--lock_global_pointer_regs` has been specified.

Special registers

For some registers, you must consider certain prerequisites:

- `R0` will act as a normal processor register with the exception that the value of the register is always zero
- `R2` is reserved for use by an operating system

- Some registers might possibly be unavailable due to register locking. For details, see *--lock_10_regs*, page 273 and *--lock_global_pointer_regs*, page 273.
- The stack pointer register must at all times point to the topmost element on the stack. If an interrupt occurs, everything on the other side of the point the stack pointer points to can be destroyed.
- The brel base pointer registers `GP` and `TP` (pointing to data areas that are addressed with indexed addressing modes) must never be changed.
- The link register holds the return address at the entrance of the function.

FUNCTION ENTRANCE

Parameters can be passed to a function using one of these basic methods:

- In registers
- On the stack

It is much more efficient to use registers than to take a detour via memory, so the calling convention is designed to use registers as much as possible. Only a limited number of registers can be used for passing parameters; when no more registers are available, the remaining parameters are passed on the stack.

Hidden parameters

In addition to the parameters visible in a function declaration and definition, there can be hidden parameters:

- If the function returns a structure, the memory location where the structure will be stored is passed as an extra parameter in register `R6`. Note that it is always treated as the *first* parameter.
- If the function is a non-static C++ member function, then the `this` pointer is passed as the first parameter in register `R6` (but placed after the return structure pointer, if there is one). The reason why the member function must be non-static is that static member methods do not have a `this` pointer.

Register parameters

The registers available for passing parameters are `R6–R9`.

Parameters	Passed in registers
8-, 16-, or 32-bit values	`R6–R9`
64-bit values	`R6:R7`, `R7:R8`, or `R8:R9`
96-bit values	`R6:R7:R8` or `R7:R8:R9`

Table 17: Registers used for passing parameters

Parameters	Passed in registers
128-bit values	R6:R7:R8:R9

Table 17: Registers used for passing parameters (Continued)

Note: Scalar parameters—integers and pointers—require one register. The same is true for `float` values. On the other hand, `double` and `long long` values require two registers.

The assignment of registers to parameters is a straightforward process. The first parameter is assigned to the first available register, the second parameter to the second available register etc. Should there be no more available registers, the parameter is passed on the stack.

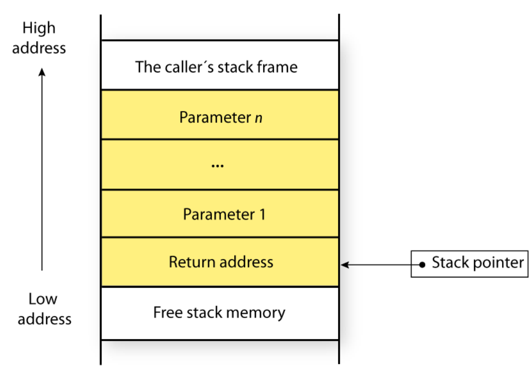
If a `struct` or an ... argument is passed and there are still parameter registers available, the beginning of the `struct` is passed to those registers.

If a `double` parameter is passed in registers, it can only be passed using a register pair listed in the table. If, for example, `R6` has been assigned to a scalar parameter, the next available register pair is `R8:R9` (assuming 8-byte alignment).

Stack parameters and layout

Stack parameters are stored in the main memory, starting at the location pointed to by the stack pointer. Below the stack pointer (toward low memory) there is free space that the called function can use. The first stack parameter is stored at the location pointed to by the stack pointer. The next one is stored at the next location on the stack that is divisible by 4, etc. (For more complex parameters, see also the Renesas ABI specification.)

This figure illustrates how parameters are stored on the stack:



FUNCTION EXIT

A function can return a value to the function or program that called it, or it can have the return type `void`.

The return value of a function, if any, can be scalar (such as integers and pointers), floating-point, or a structure.

Registers used for returning values

Scalar and `float` values are returned using register `R10`. `double` and `long long` values use the register pair `R10:R11`.

If a structure is returned, the caller of the function is responsible for allocating memory for the return value. A pointer to the memory is passed as a "hidden" first parameter that is always allocated to register `R10`. The called function must return the value of the location in register `R10`.

Stack layout at function exit

It is the responsibility of the called function to clean the stack before function exit, in other words, responsible for cleaning the pushed parameters before the function returns.

Return address handling

A function written in assembler language should, when finished, return to the caller. At a function call, the return address is stored in the return address register or registers. This is register `LP`.

Typically, a function returns by using the `JUMP` instruction, for example:

```
jmp    [LP]
```

If a function is to call another function, the original return address must be stored somewhere. This is normally done on the stack, for example:

```
name    call
section .text:CODE(2)
extern  _func
code

prepare     {lp},0
jarl        _func,lp

; Do something here.

dispose     0,{lp},[lp]

end
```

RESTRICTIONS FOR SPECIAL FUNCTION TYPES

These restrictions apply to the special function types `__callt`, `__interrupt`, `__syscall`, `__task`, and `__trap`:

- The return address is not stored in the register `LP` but in dedicated system registers.
- Interrupt functions have no scratch registers.

EXAMPLES

The following section shows a series of declaration examples and the corresponding calling conventions. The complexity of the examples increases toward the end.

Example 1

Assume this function declaration:

```
int add1(int);
```

This function takes one parameter in the register `R6`, and the return value is passed back to its caller in the register `R10`.

This assembler routine is compatible with the declaration; it will return a value that is one number higher than the value of its parameter:

```
name    return
section .text:CODE(2)
code
add     1,r6
mov     r6,r10
jmp     [lp]

end
```

Example 2

The function below will return a structure of type `struct MyStruct`.

```
struct MyStruct
{
  int mA[20];
};

struct MyStruct MyFunction(int x);
```

It is the responsibility of the calling function to allocate a memory location for the return value and pass a pointer to it as a hidden first parameter. The pointer to the location where the return value should be stored is passed in `R6`. The caller assumes that these registers remain untouched. The parameter *x* is passed in `R7`.

Assume that the function instead was declared to return a pointer to the structure:

```
struct MyStruct *MyFunction(int x);
```

In this case, the return value is a scalar, so there is no hidden parameter. The parameter `x` is passed in `R6`, and the return value is returned in `R10`.

Assembler instructions used for calling functions

This section presents the assembler instructions that can be used for calling and returning from functions on the RH850 microcontroller.

Functions can be called in different ways—directly or via a function pointer. In this section we will discuss how these types of calls will be performed .

The normal function calling instruction is the jump-and-link instruction:

```
jarl label, reg
```

The location that the called function should return to (that is, the location immediately after this instruction) is stored in the register.

The destination label cannot be further away than 2 Mbytes.

```
jmp [reg]
```

This is an instruction to jump to the location that *`reg`* points to. After the instruction has been performed, the code located at the label will start executing.

A C function, for instance `alpha`, is represented in assembler language as a label with the same name as the function, in this case `_alpha`. The location of the label is the actual location of the code of the function.

Memory access methods

This section describes the different memory types presented in the chapter *Data storage*. In addition to presenting the assembler code used for accessing data, this section will explain the reason behind the different memory types.

You should be familiar with the RH850 instruction set, in particular the different addressing modes used by the instructions that can access memory.

For each of the access methods described in the following sections, there are three examples:

- Accessing a global variable
- Accessing a global array using an unknown index

- Accessing a structure using a pointer.

These three examples can be illustrated by this C program:

```
char myVar;
char MyArr[10];

struct MyStruct
{
  long mA;
  char mB;
};

char Foo(int i, struct MyStruct *p)
{
  return myVar + MyArr[i] + p->mB;
}
```

THE NEAR MEMORY ACCESS METHOD

Near memory is the memory that is located at ±32 Kbytes around address 0. The assembler code for storing something using this memory access method is simply:

```
ST.W     R1, x[R0]
```

Remember that `R0` will act as a normal processor register with the exception that the value of the register always will be zero.

Clearly, the memory range that this assembler instruction can access is limited by the range of the displacement. Because the displacement is limited to a signed 16-bit value, only the first and last 32 Kbytes of memory can be reached.

Examples

Address of:

```
        movea       MyVar, r0, r1
```

Reading a global variable:

```
        ld.b        MyVar[zero], r1
```

Reading a global array using an unknown index:

```
        ld.b        MyArr[r1], r6
```

Reading a structure using a pointer:

```
        ld.b        (4)[r1],r1
```

THE BASE-RELATIVE MEMORY ACCESS METHOD

The base-relative (brel) access method can access two memory areas of 64 Kbytes, one in RAM and one in ROM. Unlike the near memory, the brel memory areas can be placed anywhere in memory.

There are two linker-generated assembler labels, `__iar_static_base$$GP` and `__iar_static_base$$TP`, located in the middle of the brel memory areas. The processor register `R4`—also known as `GP`—and the processor register `R5` (`TP`) are initialized to these values.

The assembler code for writing to the brel RAM area is:

```
st.w    R1, relgp(x)[GP]
```

For the brel RAM area, the displacement used is the value of the expression RELGP(x), where `x` refers to the absolute location of the variable `x`.

The assembler code for reading from the brel ROM area is:

```
ld.w    reltp(y)[TP],R1
```

It works the same way as the code for the RAM area.

Examples

Address of:

```
movea       relgp(MyVar),gp,r1
```

Reading a global variable:

```
ld.b        relgp(MyVar)[gp],r6
```

Reading a global array using an unknown index:

```
add         gp,r1
ld.b        relgp(MyArr)[r1],r7
```

Reading a structure using a pointer:

```
ld.b        (4)[r6],r1
```

THE BASE-RELATIVE23 MEMORY ACCESS METHOD

The base-relative23 (brel23) access method uses the same base pointers and placeholder segments as the normal base-relative access method, but can access 8 Mbytes of ROM and 8 Mbytes of RAM, respectively.

Examples

Address of:

```
movhi       hi1(relgp(MyVar)),gp,r1
movea       lw1(relgp(MyVar)),r1,r1
```

Reading a global variable:

```
ld.bu       M:relgp(MyVar)[gp],r6
```

Reading a global array using an unknown index:

```
add         gp,r1
Reading.bu  M:relgp(MyArr)[r1],r7
```

Reading a structure using a pointer:

```
ld.b        (4)[r6],r1
```

THE HUGE MEMORY ACCESS METHOD

It is not possible to access an arbitrary location using only one instruction. In the RH850 microcontroller, this is solved by using the `MOVHI` instruction to move part of the memory location to access to a temporary register.

For example, to store a variable `x` in huge memory, the following assembler code is used:

```
movhi   hi1(x), r0, r6
st.w    R1, lw1(x)[r6]
```

Examples

Address of:

```
mov       MyVar,r1
```

Accessing a global variable:

```
movhi       hi1(MyVar),r0,r6
ld.b        lw1(MyVar)[r6],r6
```

Accessing a global array using an unknown index:

```
movhi       hi1(MyArr),r1,r7
ld.b        lw1(MyArr)[r7],r7
```

Accessing a structure using a pointer:

```
ld.b        (4)[r6],r1
```

SHORT ADDRESSING ACCESS METHOD

The short addressing (saddr) access method uses the short variants of the load and store instructions, `SLD` and `SST`. These instructions are smaller than the standard `LD` and `ST` instructions.

The assembler label `__iar_static_base$$EP` is located at the beginning of the 256 byte memory area that can be reached using the short load and store instructions. The processor register `EP` (`R30`) is used as a base pointer to this area. Note that when you are using a data models without short addressing, the `EP` register is instead a pointer to the frame on the stack.

The source code needed to store a value to saddr memory is:

```
sst.w   R1, relep(x)[ep]
```

This instruction can only reach 256 bytes. When using byte access, it is limited to 128 bytes. This is the reason for the corresponding limitation on the data for the saddr memory type.

NO BIT ACCESS

Data objects declared `__no_bit_access` are never accessed using the RH850 bit instructions. This is primarily useful when accessing memory-mapped peripheral units that do not allow bit access.

Call frame information

When you debug an application using C-SPY, you can view the *call stack*, that is, the chain of functions that called the current function. To make this possible, the compiler supplies debug information that describes the layout of the call frame, in particular information about where the return address is stored.

If you want the call stack to be available when debugging a routine written in assembler language, you must supply equivalent debug information in your assembler source using the assembler directive `CFI`. This directive is described in detail in the *IAR Assembler Reference Guide for RH850*.

CFI DIRECTIVES

The `CFI` directives provide C-SPY with information about the state of the calling function(s). Most important of this is the return address, and the value of the stack pointer at the entry of the function or assembler routine. Given this information, C-SPY can reconstruct the state for the calling function, and thereby unwind the stack.

A full description about the calling convention might require extensive call frame information. In many cases, a more limited approach will suffice.

When describing the call frame information, the following three components must be present:

- A *names block* describing the available resources to be tracked
- A *common block* corresponding to the calling convention
- A *data block* describing the changes that are performed on the call frame. This typically includes information about when the stack pointer is changed, and when permanent registers are stored or restored on the stack.

This table lists all the resources defined in the names block used by the compiler:

Resource	Description
`R0–R2`, `R4–R29`	Normal registers
`SP` (`R3`)	The stack pointer
`EP` (`R30`)	The short address base pointer
`LP` (`R31`)	The return address register
`PSW`	The status register
`FPSR`	The floating-point status
`CTPC`	The callt return address register
`CTPSW`	The callt saved status
`EIPC`	The interrupt/syscall return address register
`EIPSW`	The interrupt/syscall saved status
`FEPC`	The exception return address register
`FEPSW`	The exception saved status

Table 18: Call frame information resources defined in a names block

CREATING ASSEMBLER SOURCE WITH CFI SUPPORT

The recommended way to create an assembler language routine that handles call frame information correctly is to start with an assembler language source file created by the compiler.

1 Start with suitable C source code, for example:

```
int F(int);
int cfiExample(int i)
{
  return i + F(i);
}
```

2 Compile the C source code, and make sure to create a list file that contains call frame information—the CFI directives.

On the command line, use the option `-lA`.

In the IDE, choose **Project>Options>C/C++ Compiler>List** and make sure the suboption **Include call frame information** is selected.

For the source code in this example, the list file looks like this:

```
NAME test

RTMODEL "__SystemLibrary", "DLib"
RTMODEL "__core", "g3"
RTMODEL "__data_model", "tiny"
RTMODEL "__double_size", "64"
RTMODEL "__eight_byte_alignment", "disabled"
RTMODEL "__enum_size", "*"
RTMODEL "__fpu", "double"
RTMODEL "__reg_ep", "frame"
RTMODEL "__reg_gp_lock", "0"
RTMODEL "__reg_r5", "brel_const"
RTMODEL "__rt_version", "2"

#define SHT_PROGBITS 0x1

EXTERN _F

PUBLIC _cfiExample

  CFI Names cfiNames0
  CFI StackFrame CFA SP DATA
  CFI Resource R0:32, R1:32, R2:32, SP:32, R4:32, R5:32,
               R6:32, R7:32
  CFI Resource R8:32, R9:32, R10:32, R11:32, R12:32,
               R13:32, R14:32
  CFI Resource R15:32, R16:32, R17:32, R18:32, R19:32,
               R20:32, R21:32
  CFI Resource R22:32, R23:32, R24:32, R25:32, R26:32,
               R27:32, R28:32
  CFI Resource R29:32, EP:32, LP:32, EIPC:32, EIPSW:32,
               FEPC:32, FEPSW:32
  CFI Resource PSW:32, CTPC:32, CTPSW:32
  CFI VirtualResource ?RET:32
  CFI EndNames cfiNames0
```

```
CFI Common cfiCommon0 Using cfiNames0
CFI CodeAlign 2
CFI DataAlign 4
CFI ReturnAddress ?RET DATA
CFI CFA SP+0
CFI R0 SameValue
CFI R1 Undefined
CFI R2 SameValue
CFI R4 SameValue
CFI R5 SameValue
CFI R6 Undefined
CFI R7 Undefined
CFI R8 Undefined
CFI R9 Undefined
CFI R10 Undefined
CFI R11 Undefined
CFI R12 Undefined
CFI R13 Undefined
CFI R14 Undefined
CFI R15 Undefined
CFI R16 Undefined
CFI R17 Undefined
CFI R18 Undefined
CFI R19 Undefined
CFI R20 SameValue
CFI R21 SameValue
CFI R22 SameValue
CFI R23 SameValue
CFI R24 SameValue
CFI R25 SameValue
CFI R26 SameValue
CFI R27 SameValue
CFI R28 SameValue
CFI R29 SameValue
CFI EP SameValue
CFI LP Undefined
CFI EIPC SameValue
CFI EIPSW SameValue
CFI FEPC SameValue
CFI FEPSW SameValue
CFI PSW SameValue
CFI CTPC SameValue
CFI CTPSW SameValue
CFI ?RET LP
CFI EndCommon cfiCommon0
```

```
        SECTION `.text`:CODE:NOROOT(2)
          CFI Block cfiBlock0 Using cfiCommon0
          CFI Function _cfiExample
        CODE
_cfiExample:
        PREPARE     {r29,lp},0
          CFI R29 Frame(CFA, -4)
          CFI ?RET Frame(CFA, -8)
          CFI CFA SP+8
        MOV         r6,r29
        MOV         r29,r6
          CFI FunCall _F
        JARL        _F,lp
        ADD         r29,r10
        DISPOSE     0,{r29,lp},[lp]
          CFI EndBlock cfiBlock0

        SECTION `.iar_vfe_header`:DATA:NOALLOC:NOROOT(2)
        SECTION_TYPE SHT_PROGBITS, 0
        DATA
        DC32 0
        END
```

Note: The header file `cfi.h` contains the macros `CFNAMES` and `CFCOMMON0`, which declare a typical names block and a typical common block. These two macros declare several resources, both concrete and virtual.

Using C

- C language overview
- Extensions overview
- IAR C language extensions

C language overview

The IAR C/C++ Compiler for RH850 supports the INCITS/ISO/IEC 9899:2018 standard, also known as C18. C18 addresses defects in C11 (INCITS/ISO/IEC 9899:2012) without introducing any new language features. This means that the C11 standard is also supported. In this guide, the C18 standard is referred to as *Standard C* and is the default standard used in the compiler. This standard is stricter than C89.

The compiler will accept source code written in the C18 standard or a superset thereof.

In addition, the compiler also supports the ISO 9899:1990 standard (including all technical corrigenda and addenda), also known as C94, C90, C89, and ANSI C. In this guide, this standard is referred to as *C89*. Use the `--c89` compiler option to enable this standard.

With Standard C enabled, the IAR C/C++ Compiler for RH850 can compile all C18/C11 source code files, except for those that depend on thread-related system header files.

The floating-point standard that Standard C binds to is IEC 60559—known as ISO/IEC/IEEE 60559—which is nearly identical to IEEE 754 format.

Annex K (*Bounds-checking interfaces*) of the C standard is supported. See *Bounds checking functionality*, page 134.

For an overview of the differences between the various versions of the C standard, see the Wikipedia articles *C18 (C standard revision)*, *C11 (C standard revision)*, or *C99*.

Extensions overview

The compiler offers the features of Standard C and a wide set of extensions, ranging from features specifically tailored for efficient programming in the embedded industry to the relaxation of some minor standards issues.

This is an overview of the available extensions:

- *IAR C language extensions*

  For information about available language extensions, see *IAR C language extensions*, page 189. For more information about the extended keywords, see the chapter *Extended keywords*. For information about C++, the two levels of support for the language, and C++ language extensions, see the chapter *Using C++*.

- *Pragma directives*

  The `#pragma` directive is defined by Standard C and is a mechanism for using vendor-specific extensions in a controlled way to make sure that the source code is still portable.

  The compiler provides a set of predefined pragma directives, which can be used for controlling the behavior of the compiler, for example, how it allocates memory, whether it allows extended keywords, and whether it outputs warning messages. Most pragma directives are preprocessed, which means that macros are substituted in a pragma directive. The pragma directives are always enabled in the compiler. For several of them there is also a corresponding C/C++ language extension. For information about available pragma directives, see the chapter *Pragma directives*.

- *Preprocessor extensions*

  The preprocessor of the compiler adheres to Standard C. The compiler also makes several preprocessor-related extensions available to you. For more information, see the chapter *The preprocessor*.

- *Intrinsic functions*

  The intrinsic functions provide direct access to low-level processor operations and can be useful in, for example, time-critical routines. The intrinsic functions compile into inline code, either as a single instruction or as a short sequence of instructions. For more information about using intrinsic functions, see *Mixing C and assembler*, page 161. For information about available functions, see the chapter *Intrinsic functions*.

- *Library functions*

  The DLIB runtime environment provides the C and C++ library definitions in the C/C++ standard library that apply to embedded systems. For more information, see *DLIB runtime environment—implementation details*, page 413.

Note: Any use of these extensions, except for the pragma directives, makes your source code inconsistent with Standard C.

ENABLING LANGUAGE EXTENSIONS

You can choose different levels of language conformance by means of project options:

Command line	IDE*	Description
`--strict`	**Strict**	All IAR C language extensions are disabled—errors are issued for anything that is not part of Standard C.
None	**Standard**	All *extensions to Standard C* are enabled, but no *extensions for embedded systems programming*. For information about extensions, see *IAR C language extensions*, page 189.
`-e`	**Standard with IAR extensions**	All *IAR C language extensions* are enabled.

Table 19: Language extensions

* In the IDE, choose **Project>Options>C/C++ Compiler>Language 1>Language conformance** and select the appropriate option. Note that language extensions are enabled by default.

IAR C language extensions

The compiler provides a wide set of C language extensions. To help you to find the extensions required by your application, they are grouped like this in this section:

- *Extensions for embedded systems programming*—extensions specifically tailored for efficient embedded programming for the specific microcontroller you are using, typically to meet memory restrictions
- *Relaxations to Standard C*—that is, the relaxation of some minor Standard C issues and also some useful but minor syntax extensions, see *Relaxations to Standard C*, page 191.

EXTENSIONS FOR EMBEDDED SYSTEMS PROGRAMMING

The following language extensions are available both in the C and the C++ programming languages and they are well suited for embedded systems programming:

- *Memory attributes, type attributes, and object attributes*

  For information about the related concepts, the general syntax rules, and for reference information, see the chapter *Extended keywords*.
- *Placement at an absolute address or in a named section*

  The `@` operator or the directive `#pragma location` can be used for placing global and static variables at absolute addresses, or placing a variable or function in a named section. For more information about using these features, see *Controlling data and function placement in memory*, page 224, and *location*, page 373.

- *Alignment control*

  Each data type has its own alignment. For more information, see *Alignment*, page 327. If you want to change the alignment, the `#pragma pack`, and the `#pragma data_alignment` directives are available. If you want to check the alignment of an object, use the `__ALIGNOF__()` operator.

  The `__ALIGNOF__` operator is used for accessing the alignment of an object. It takes one of two forms:

  - `__ALIGNOF__ (`*`type`*`)`
  - `__ALIGNOF__ (`*`expression`*`)`

  In the second form, the expression is not evaluated.

  See also the Standard C file `stdalign.h`.

- *Bitfields and non-standard types*

  In Standard C, a bitfield must be of the type `int` or `unsigned int`. Using IAR C language extensions, any integer type or enumeration can be used. The advantage is that the struct will sometimes be smaller. For more information, see *Bitfields*, page 330.

Dedicated section operators

The compiler supports getting the start address, end address, and size for a section with these built-in section operators:

`__section_begin`	Returns the address of the first byte of the named section or block.
`__section_end`	Returns the address of the first byte *after* the named section or block.
`__section_size`	Returns the size of the named section or block in bytes.

Note: The aliases `__segment_begin`/`__sfb`, `__segment_end`/`__sfe`, and `__segment_size`/`__sfs` can also be used.

The operators can be used on named sections or on named blocks defined in the linker configuration file.

These operators behave syntactically as if declared like:

```
void * __section_begin(char const * section)
void * __section_end(char const * section)
size_t __section_size(char const * section)
```

When you use the @ operator or the #pragma location directive to place a data object or a function in a user-defined section, or when you use named blocks in the linker configuration file, the section operators can be used for getting the start and end address of the memory range where the sections or blocks were placed.

The named *section* must be a string literal and it must have been declared earlier with the #pragma *section* directive. If the section was declared with a memory attribute *memattr*, the type of the __section_begin operator is a pointer to *memattr* void. Otherwise, the type is a default pointer to void. Note that you must enable language extensions to use these operators.

The operators are implemented in terms of *symbols* with dedicated names, and will appear in the linker map file under these names:

Operator	Symbol
__section_begin(sec)	sec$$Base
__section_end(sec)	sec$$Limit
__section_size(sec)	sec$$Length

Table 20: Section operators and their symbols

Note: The linker will not necessarily place sections with the same name consecutively when these operators are not used. Using one of these operators (or the equivalent symbols) will cause the linker to behave as if the sections were in a named block. This is to assure that the sections are placed consecutively, so that the operators can be assigned meaningful values. If this is in conflict with the section placement as specified in the linker configuration file, the linker will issue an error.

Example

In this example, the type of the __section_begin operator is void __brel *.

```
#pragma section="MYSECTION" __brel
...
section_start_address = __section_begin("MYSECTION");
```

See also *section*, page 379, and *location*, page 373.

RELAXATIONS TO STANDARD C

This section lists and briefly describes the relaxation of some Standard C issues and also some useful but minor syntax extensions:

- Arrays of incomplete types

  An array can have an incomplete struct, union, or enum type as its element type. The types must be completed before the array is used (if it is), or by the end of the compilation unit (if it is not).

- Forward declaration of `enum` types

  The extensions allow you to first declare the name of an `enum` and later resolve it by specifying the brace-enclosed list.

- Accepting missing semicolon at the end of a `struct` or `union` specifier

  A warning—instead of an error—is issued if the semicolon at the end of a `struct` or `union` specifier is missing.

- Null and `void`

  In operations on pointers, a pointer to `void` is always implicitly converted to another type if necessary, and a null pointer constant is always implicitly converted to a null pointer of the right type if necessary. In Standard C, some operators allow this kind of behavior, while others do not allow it.

- Casting pointers to integers in static initializers

  In an initializer, a pointer constant value can be cast to an integral type if the integral type is large enough to contain it. For more information about casting pointers, see *Casting*, page 334.

- Taking the address of a register variable

  In Standard C, it is illegal to take the address of a variable specified as a register variable. The compiler allows this, but a warning is issued.

- `long float` means `double`

  The type `long float` is accepted as a synonym for `double`.

- Repeated `typedef` declarations

  Redeclarations of `typedef` that occur in the same scope are allowed, but a warning is issued.

- Mixing pointer types

  Assignment and pointer difference is allowed between pointers to types that are interchangeable but not identical, for example, `unsigned char *` and `char *`. This includes pointers to integral types of the same size. A warning is issued.

  Assignment of a string constant to a pointer to any kind of character is allowed, and no warning is issued.

- Non-`lvalue` arrays

  A non-`lvalue` array expression is converted to a pointer to the first element of the array when it is used.

- Comments at the end of preprocessor directives

  This extension, which makes it legal to place text after preprocessor directives, is enabled unless the strict Standard C mode is used. The purpose of this language extension is to support compilation of legacy code—we do not recommend that you write new code in this fashion.

- An extra comma at the end of `enum` lists

  Placing an extra comma is allowed at the end of an `enum` list. In strict Standard C mode, a warning is issued.

- A label preceding a `}`

  In Standard C, a label must be followed by at least one statement. Therefore, it is illegal to place the label at the end of a block. The compiler allows this, but issues a warning. Note that this also applies to the labels of `switch` statements.

- Empty declarations

  An empty declaration (a semicolon by itself) is allowed, but a remark is issued (provided that remarks are enabled).

- Single-value initialization

  Standard C requires that all initializer expressions of static arrays, structs, and unions are enclosed in braces.

  Single-value initializers are allowed to appear without braces, but a warning is issued. The compiler accepts this expression:

  ```
  struct str
  {
    int a;
  } x = 10;
  ```

- Declarations in other scopes

  External and static declarations in other scopes are visible. In the following example, the variable `y` can be used at the end of the function, even though it should only be visible in the body of the `if` statement. A warning is issued.

  ```
  int test(int x)
  {
    if (x)
    {
      extern int y;
      y = 1;
    }

    return y;
  }
  ```

- Static functions in function and block scopes

  Static functions may be declared in function and block scopes. Their declarations are moved to the file scope.

- Numbers scanned according to the syntax for numbers

  Numbers are scanned according to the syntax for numbers rather than the `pp-number` syntax. Therefore, `0x123e+1` is scanned as three tokens instead of one valid token. (If the `--strict` option is used, the `pp-number` syntax is used instead.)

- Empty translation unit

  A translation unit (input file) might be empty of declarations.

- Assignment of pointer types

  Assignment of pointer types is allowed in cases where the destination type has added type qualifiers that are not at the top level, for example, `int **` to `const int **`. Comparisons and pointer difference of such pairs of pointer types are also allowed. A warning is issued.

- Pointers to different function types

  Pointers to different function types might be assigned or compared for equality (`==`) or inequality (`!=`) without an explicit type cast. A warning is issued. This extension is not allowed in C++ mode.

- Assembler statements

  Assembler statements are accepted. This is disabled in strict C mode because it conflicts with the C standard for a call to the implicitly declared `asm` function.

- `#include_next`

  The non-standard preprocessing directive `#include_next` is supported. This is a variant of the `#include` directive. It searches for the named file only in the directories on the search path that follow the directory in which the current source file (the one containing the `#include_next` directive) is found. This is an extension found in the GNU C compiler.

- `#warning`

  The non-standard preprocessing directive `#warning` is supported. It is similar to the `#error` directive, but results in a warning instead of a catastrophic error when processed. This directive is not recognized in strict mode. This is an extension found in the GNU C compiler.

- Concatenating strings

  Mixed string concatenations are accepted.

  ```
  wchar_t * str="a" L "b";
  ```

Using C++

- Overview—Standard C++
- Enabling support for C++
- C++ feature descriptions
- C++ language extensions
- Porting code from EC++ or EEC++

Overview—Standard C++

The IAR C++ implementation fully complies with the ISO/IEC 14882:2015 C++ standard, except for source code that depends on thread-related system headers.

Atomic operations are available for cores where the instruction set supports them. See *Atomic operations*, page 419.

The ISO/IEC 14882:2015 C++ standard is also known as C++14. In this guide, this standard is referred to as Standard C++.

The IAR C/C++ compiler accepts source code written in the C++14 standard or a superset thereof.

For an overview of the differences between the various versions of the C++ standard, see the Wikipedia articles *C++17*, *C++14*, *C++11*, or *C++* (for information about C++98).

EXCEPTIONS AND RTTI

Exceptions and RTTI are not supported. Thus, the following are not allowed:

- `throw` expressions
- `try-catch` statements
- Exception specifications on function definitions
- The `typeid` operator
- The `dynamic_cast` operator

Enabling support for C++

In the compiler, the default language is C.

To compile files written in Standard C++, use the `--c++` compiler option. See *--c++*, page 260.

To enable C++ in the IDE, choose **Project>Options>C/C++ Compiler>Language 1>Language>C++**.

C++ feature descriptions

When you write C++ source code for the IAR C/C++ Compiler for RH850, you must be aware of some benefits and some possible quirks when mixing C++ features—such as classes, and class members—with IAR language extensions, such as IAR-specific attributes.

USING IAR ATTRIBUTES WITH CLASSES

Static data members of C++ classes are treated the same way global variables are, and can have any applicable IAR type, memory, and object attribute.

Member functions are in general treated the same way free functions are, and can have any applicable IAR type, memory, and object attributes. Virtual member functions can only have attributes that are compatible with default function pointers, and constructors and destructors cannot have any such attributes.

The location operator `@` and the `#pragma location` directive can be used on static data members and with all member functions.

Example of using attributes with classes

```
class MyClass
{
public:
  // Locate a static variable in near memory at address FFFF8000
  static __near __no_init int mI @ 0xFFFF8000;

  // A static function using the callt call mechanism
  static __callt void F();

  // A function using the trap call mechanism
  __trap void G();

  // Locate a virtual function in default memory
  virtual void H();

  // Locate a virtual function into SPECIAL
  virtual void M() const volatile @ "SPECIAL";
};
```

TEMPLATES

C++ supports templates according to the C++ standard. The implementation uses a two-phase lookup which means that the keyword `typename` must be inserted wherever needed. Furthermore, at each use of a template, the definitions of all possible templates must be visible. This means that the definitions of all templates must be in include files or in the actual source file.

FUNCTION TYPES

A function type with `extern "C"` linkage is compatible with a function that has C++ linkage.

Example

```
extern "C"
{
  typedef void (*FpC)(void);      // A C function typedef
}

typedef void (*FpCpp)(void);    // A C++ function typedef

FpC F1;
FpCpp F2;
void MyF(FpC);

void MyG()
{
  MyF(F1);                        // Always works
  MyF(F2);                        // FpCpp is compatible with FpC
}
```

USING STATIC CLASS OBJECTS IN INTERRUPTS

If interrupt functions use static class objects that need to be constructed (using constructors) or destroyed (using destructors), your application will not work properly if the interrupt occurs before the objects are constructed, or, during or after the objects are destroyed.

To avoid this, make sure that these interrupts are not enabled until the static objects have been constructed, and are disabled when returning from `main` or calling `exit`. For information about system startup, see *System startup and termination*, page 142.

Function local static class objects are constructed the first time execution passes through their declaration, and are destroyed when returning from `main` or when calling `exit`.

USING NEW HANDLERS

To handle memory exhaustion, you can use the `set_new_handler` function.

If you do not call `set_new_handler`, or call it with a NULL `new` handler, and `operator new` fails to allocate enough memory, it will call `abort`. The `nothrow` variant of the `new` operator will instead return NULL.

If you call `set_new_handler` with a non-NULL `new` handler, the provided `new` handler will be called by `operator new` if `operator new` fails to allocate memory. The `new` handler must then make more memory available and return, or abort execution in some manner. The `nothrow` variant of `operator new` will never return NULL in the presence of a `new` handler.

This is the same behavior as using the `nothrow` variants of `new`.

DEBUG SUPPORT IN C-SPY

C-SPY® has built-in display support for the STL containers. The logical structure of containers is presented in the watch views in a comprehensive way that is easy to understand and follow.

For more information, see the *C-SPY® Debugging Guide for RH850*.

C++ language extensions

When you use the compiler in C++ mode and enable IAR language extensions, the following C++ language extensions are available in the compiler:

- In a `friend` declaration of a class, the `class` keyword can be omitted, for example:

```
class B;
class A
{
  friend B;       //Possible when using IAR language
                  //extensions
  friend class B; //According to the standard
};
```

- In the declaration of a class member, a qualified name can be used, for example:

```
struct A
{
  int A::F(); // Possible when using IAR language extensions
  int G();    // According to the standard
};
```

- It is permitted to use an implicit type conversion between a pointer to a function with C linkage (`extern "C"`) and a pointer to a function with C++ linkage (`extern "C++"`), for example:

```
extern "C" void F(); // Function with C linkage
void (*PF)()       // PF points to a function with C++ linkage
             = &F; // Implicit conversion of function pointer.
```

  According to the standard, the pointer must be explicitly converted.

- If the second or third operands in a construction that contains the `?` operator are string literals or wide string literals—which in C++ are constants—the operands can be implicitly converted to `char *` or `wchar_t *`, for example:

```
bool X;

char *P1 = X ? "abc" : "def";       //Possible when using IAR
                                    //language extensions
char const *P2 = X ? "abc" : "def";//According to the standard
```

- Default arguments can be specified for function parameters not only in the top-level function declaration, which is according to the standard, but also in `typedef` declarations, in pointer-to-function function declarations, and in pointer-to-member function declarations.
- In a function that contains a non-static local variable and a class that contains a non-evaluated expression—for example a `sizeof` expression—the expression can reference the non-static local variable. However, a warning is issued.
- An anonymous union can be introduced into a containing class by a `typedef` name. It is not necessary to first declare the union. For example:

```
typedef union
{
  int i,j;
} U;  // U identifies a reusable anonymous union.

class A
{
public:
  U;  // OK -- references to A::i and A::j are allowed.
};
```

  In addition, this extension also permits *anonymous classes* and *anonymous structs*, as long as they have no C++ features—for example, no static data members or member functions, and no non-public members—and have no nested types other than other anonymous classes, structs, or unions. For example:

```
struct A
{
  struct
  {
    int i,j;
  }; // OK -- references to A::i and A::j are allowed.
};
```

- The friend class syntax allows nonclass types as well as class types expressed through a `typedef` without an elaborated type name. For example:

```
typedef struct S ST;

class C
{
public:
  friend S;  // Okay (requires S to be in scope)
  friend ST; // Okay (same as "friend S;")
  // friend S const; // Error, cv-qualifiers cannot
                     // appear directly
};
```

- It is allowed to specify an array with no size or size 0 as the last member of a struct. For example:

  ```
  typedef struct
  {
    int i;
    char ir[0]; // Zero-length array
  };

  typedef struct
  {
    int i;
    char ir[];  // Zero-length array
  };
  ```
- Arrays of incomplete types

  An array can have an incomplete `struct`, `union`, `enum`, or `class` type as its element type. The types must be completed before the array is used—if it is— or by the end of the compilation unit—if it is not.
- Concatenating strings

  Mixed string literal concatenations are accepted.

  ```
  wchar_t * str = "a" L "b";
  ```
- Trailing comma

  A trailing comma in the definition of an enumeration type is silently accepted.

Except where noted, all of the extensions described for C are also allowed in C++ mode.

Note: If you use any of these constructions without first enabling language extensions, errors are issued.

Porting code from EC++ or EEC++

Apart from the fact that Standard C++ is a much larger language than EC++ or EEC++, there are two issues that might prevent EC++ and EEC++ code from compiling:

- The library is placed in `namespace std`.

  There are two remedy options:
  - Prefix each used library symbol with `std::`.
  - Insert `using namespace std;` after the last include directive for a C++ system header file.
- Some library symbols have changed names or parameter passing.

  To resolve this, look up the new names and parameter passing.

Application-related considerations

- Output format considerations
- Stack considerations
- Heap considerations
- Multicore RH850 microcontrollers
- Interaction between the tools and your application
- Checksum calculation for verifying image integrity
- Register locking
- Patching symbol definitions using $Super$$ and $Sub$$

Output format considerations

The linker produces an absolute executable image in the ELF/DWARF object file format.

You can use the IAR ELF Tool—`ielftool`— to convert an absolute ELF image to a format more suitable for loading directly to memory, or burning to a PROM or flash memory etc.

`ielftool` can produce these output formats:

- Plain binary
- Motorola S-records
- Intel hex.

For a complete list of supported output formats, run `ielftool` without options.

Note: `ielftool` can also be used for other types of transformations, such as filling and calculating checksums in the absolute image.

The source code for `ielftool` is provided in the `rh850/src` directory. For more information about `ielftool`, see *The IAR ELF Tool—ielftool*, page 486.

Stack considerations

To make your application use stack memory efficiently, there are some considerations to be made.

STACK SIZE CONSIDERATIONS

The required stack size depends heavily on the application's behavior. If the given stack size is too large, RAM will be wasted. If the given stack size is too small, one of two things can happen, depending on where in memory you located your stack:

- Variable storage will be overwritten, leading to undefined behavior
- The stack will fall outside of the memory area, leading to an abnormal termination of your application.

Both alternatives are likely to result in application failure. Because the second alternative is easier to detect, you should consider placing your stack so that it grows toward the end of the memory.

For more information about the stack size, see *Setting up stack memory*, page 112, and *Saving stack space and RAM memory*, page 234.

Heap considerations

The heap contains dynamic data allocated by use of the C function `malloc` (or a corresponding function) or the C++ operator `new`.

If your application uses dynamic memory allocation, you should be familiar with:

- The use of advanced, basic, and no-free heap memory allocation
- Linker sections used for the heap
- Allocating the heap size, see *Setting up heap memory*, page 112.

ADVANCED, BASIC, AND NO-FREE HEAP

The system library contains three separate heap memory handlers—the *basic*, the *advanced*, and the *no-free* heap handler.

- If there are calls to heap memory allocation routines in your application, but no calls to heap deallocation routines, the linker automatically chooses the no-free heap.
- If there are calls to heap memory allocation routines in your application, the linker automatically chooses the advanced heap.
- If there are calls to heap memory allocation routines in, for example, the library, the linker automatically chooses the basic heap.

Note: If your product has a size-limited KickStart license, the basic heap is automatically chosen.

You can use a linker option to explicitly specify which handler you want to use:

- The basic heap (`--basic_heap`) is a simple heap allocator, suitable for use in applications that do not use the heap very much. In particular, it can be used in applications that only allocate heap memory and never free it. The basic heap is not particularly speedy, and using it in applications that repeatedly free memory is quite likely to lead to unneeded fragmentation of the heap. The code for the basic heap is significantly smaller than that for the advanced heap. See *--basic_heap*, page 299.
- The advanced heap (`--advanced_heap`) provides efficient memory management for applications that use the heap extensively. In particular, applications that repeatedly allocate and free memory will likely get less overhead in both space and time. The code for the advanced heap is significantly larger than that for the basic heap. See *--advanced_heap*, page 299. For information about the definition, see *iar_dlmalloc.h*, page 420.
- The no-free heap (`--no_free_heap`) is the smallest possible heap implementation. This heap does not support `free` or `realloc`. See *--no_free_heap*, page 315.

HEAP SECTIONS IN DLIB

The memory allocated to the heap is placed in the section `HEAP`, which is only included in the application if dynamic memory allocation is actually used.

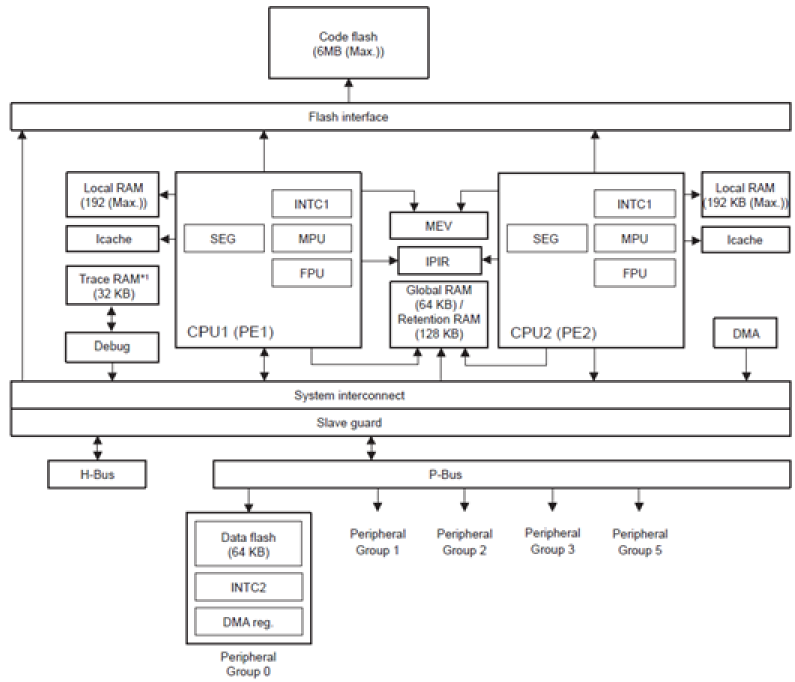
HEAP SIZE AND STANDARD I/O

If you excluded `FILE` descriptors from the DLIB runtime environment, as in the Normal configuration, there are no input and output buffers at all. Otherwise, as in the Full configuration, be aware that the size of the input and output buffers is set to 512 bytes in the `stdio` library header file. If the heap is too small, I/O will not be buffered, which is considerably slower than when I/O is buffered. If you execute the application using the simulator driver of the IAR C-SPY® Debugger, you are not likely to notice the speed penalty, but it is quite noticeable when the application runs on an RH850 microcontroller. If you use the standard I/O library, you should set the heap size to a value which accommodates the needs of the standard I/O buffer.

Multicore RH850 microcontrollers

RH850 is as a symmetric multi-core (SMP) microcontroller, which means that there are two or more identical CPUs on the same physical integrated circuit.

This figure describes RH850/F1H, which is a dual core MCU.



Each CPU has a high-speed accessible Local RAM. In addition, there is a common Global RAM for data sharing among the CPUs. A part of the global RAM area works as a retention RAM, which means that the content is kept as long the power supply voltage is sufficient. The code flash memory is used as application storage. All cores share the code flash via an interface. The data flash is a shared rewritable flash memory that supports more rewrites than the code flash memory.

On a dual-core microcontroller, two applications can be executed independently by separate cores without interfering with each other. If data needs to be passed between the applications, both cores have access to the global RAM. Because the global RAM supports instruction-fetch, it also supports function sharing. By default, each core also has its own stack located in the local RAM.

PROGRAMMING MULTICORE MICROCONTROLLERS

Programming for a multicore microcontroller requires some extra considerations:

- Configuring the shared RAM, see *Shared RAM areas*, page 111.
- Specifying separate interrupt service routines, see *#pragma core*, page 364.

- Linker sections for multicore support, see the chapter *Section reference*, page 457.

For information about debugging a multicore microcontroller, see the *C-SPY® Debugging Guide for RH850*.

Adapting the system initialization for multiple cores

In the file containing the startup code (`cstartup`), all cores initialize their own system registers and the variables located in their own local RAM. Core 1 (PE1) will also initialize all global RAM areas and the C++ constructors, while the other cores wait for it to complete. The synchronization is handled by using the Exclusive Control Register 0 (`G0MEV0`) as a semaphore. Alternatively, each core can handle its own low-level initialization in the routine `__low_level_init`, which is called from `cstartup` with a parameter that specifies which CPU core that is calling it.

For more information about system initialization, see *System initialization*, page 146.

Interaction between the tools and your application

The linking process and the application can interact symbolically in four ways:

- Creating a symbol by using the linker command line option `--define_symbol`. The linker will create a public absolute constant symbol that the application can use as a label, as a size, as setup for a debugger, etc.
- Creating an exported configuration symbol by using the command line option `--config_def` or the configuration directive `define symbol`, and exporting the symbol using the `export symbol` directive. ILINK will create a public absolute constant symbol that the application can use as a label, as a size, as setup for a debugger, etc.

  One advantage of this symbol definition is that this symbol can also be used in expressions in the configuration file, for example, to control the placement of sections into memory ranges.
- Using the compiler operators `__section_begin`, `__section_end`, or `__section_size`, or the assembler operators `SFB`, `SFE`, or `SIZEOF` on a named section or block. These operators provide access to the start address, end address, and size of a contiguous sequence of sections with the same name, or of a linker block specified in the linker configuration file.
- The command line option `--entry` informs the linker about the start label of the application. It is used by the linker as a root symbol and to inform the debugger where to start execution.

The following lines illustrate how to use `-D` to create a symbol. If you need to use this mechanism, add these options to your command line like this:

```
--define_symbol NrOfElements=10
--config_def HEAP_SIZE=1024
```

The linker configuration file can look like this:

```
define memory Mem with size = 4G;
define region ROM = Mem:[from 0x00000 size 0x10000];
define region RAM = Mem:[from 0x20000 size 0x10000];

/* Export of symbol */
export symbol MY_HEAP_SIZE;

/* Setup a heap area with a size defined by an ILINK option */
define block MyHEAP with size = MY_HEAP_SIZE, alignment = 8 {};

place in RAM { block MyHEAP };
```

Add these lines to your application source code:

```
#include <stdlib.h>

/* Use symbol defined by ILINK option to dynamically allocate an
array of elements with specified size. The value takes the form
of a label.
 */
extern int NrOfElements;

typedef char Elements;
Elements *GetElementArray()
{
  return malloc(sizeof(Elements) * (long) &NrOfElements);
}

/* Use a symbol defined by ILINK option, a symbol that in the
 * configuration file was made available to the application.
 */
extern char MY_HEAP_SIZE;
```

```
/* Declare the section that contains the heap. */
#pragma section = "MYHEAP"

char *MyHeap()
{
  /* First get start of statically allocated section, */
  char *p = __section_begin("MYHEAP");

  /* ...then we zero it, using the imported size. */
  for (int i = 0; i < (int) &MY_HEAP_SIZE; ++i)
  {
    p[i] = 0;
  }
  return p;
}
```

Checksum calculation for verifying image integrity

This section contains information about checksum calculation:

For more information, see also *The IAR ELF Tool—ielftool*, page 486.

BRIEFLY ABOUT CHECKSUM CALCULATION

You can use a checksum to verify that the image is the same at runtime as when the image's original checksum was generated. In other words, to verify that the image has not been corrupted.

This works as follows:

- You need an initial checksum.

  You can either use the IAR ELF Tool—`ielftool`—to generate an initial checksum or you might have a third-party checksum available.
- You must generate a second checksum during runtime.

  You can either add specific code to your application source code for calculating a checksum during runtime or you can use some dedicated hardware on your device for calculating a checksum during runtime.
- You must add specific code to your application source code for comparing the two checksums and take an appropriate action if they differ.

If the two checksums have been calculated in the same way, and if there are no errors in the image, the checksums should be identical. If not, you should first suspect that the two checksums were not generated in the same way.

No matter which solutions you use for generating the two checksum, you must make sure that both checksums are calculated *in the exact same way*. If you use `ielftool` for the initial checksum and use a software-based calculation during runtime, you have full control of the generation for both checksums. However, if you are using a third-party checksum for the initial checksum or some hardware support for the checksum calculation during runtime, there might be additional requirements that you must consider.

For the two checksums, there are some choices that you must always consider and there are some choices to make only if there are additional requirements. Still, all of the details must be the same for both checksums.

Always consider:

- *Checksum range*

  The memory range (or ranges) that you want to verify by means of checksums. Typically, you might want to calculate a checksum for all ROM memory. However, you might want to calculate a checksum only for specific ranges. Remember that:

  - It is OK to have several ranges for one checksum.
  - The checksum must be calculated from the lowest to the highest address for every memory range.
  - Each memory range must be verified in the same order as defined, for example, `0x100-0x1FF,0x400-0x4FF` is not the same as `0x400-0x4FF,0x100-0x1FF`.
  - If several checksums are used, you should place them in sections with unique names and use unique symbol names.
  - A checksum should never be calculated on a memory range that contains a checksum or a software breakpoint.

- *Algorithm and size of checksum*

  You should consider which algorithm is most suitable in your case. There are two basic choices, Sum—a simple arithmetic algorithm—or CRC—which is the most commonly used algorithm. For CRC there are different sizes to choose for the checksum, 2, 4, or 8 bytes where the predefined polynomials are wide enough to suit the size, for more error detecting power. The predefined polynomials work well for most, but possibly not for all data sets. If not, you can specify your own polynomial. If you just want a decent error detecting mechanism, use the predefined CRC algorithm for your checksum size, typically CRC16 or CRC32.

Note: For an *n*-bit polynomial, the *n*:th bit is always considered to be set. For a 16-bit polynomial—for example, CRC16—this means that `0x11021` is the same as `0x1021`.

For more information about selecting an appropriate polynomial for data sets with non-uniform distribution, see for example section 3.5.3 in *Tannenbaum, A.S., Computer Networks, Prentice Hall 1981, ISBN: 0131646990.*

- *Fill*

  Every byte in the checksum range must have a well-defined value before the checksum can be calculated. Typically, bytes with unknown values are *pad bytes* that have been added for alignment. This means that you must specify which fill pattern to be used during calculation, typically `0xFF` or `0x00`.

- *Initial value*

  The checksum must always have an explicit initial value.

- *Alignment*

  Because the RH850 microcontroller has alignment requirements for data accesses, you must specify the same alignment for the checksum.

In addition to these mandatory details, there might be other details to consider. Typically, this might happen when you have a third-party checksum, you want the checksum be compliant with the Rocksoft™ checksum model, or when you use hardware support for generating a checksum during runtime. `ielftool` also provides support for controlling alignment, complement, bit order, byte order within words, and checksum unit size.

CALCULATING AND VERIFYING A CHECKSUM

In this example procedure, a checksum is calculated for ROM memory from `0x8002` up to `0x8FFF` and the 2-byte calculated checksum is placed at `0x8000`.

1 If you are using `ielftool` from the command line, you must first allocate a memory location for the calculated checksum.

Note: If you instead are using the IDE (and not the command line), the `__checksum`, `__checksum_begin`, and `__checksum_end` symbols, and the `.checksum` section are *automatically* allocated when you calculate the checksum, which means that you can skip this step.

You can allocate the memory location in two ways:

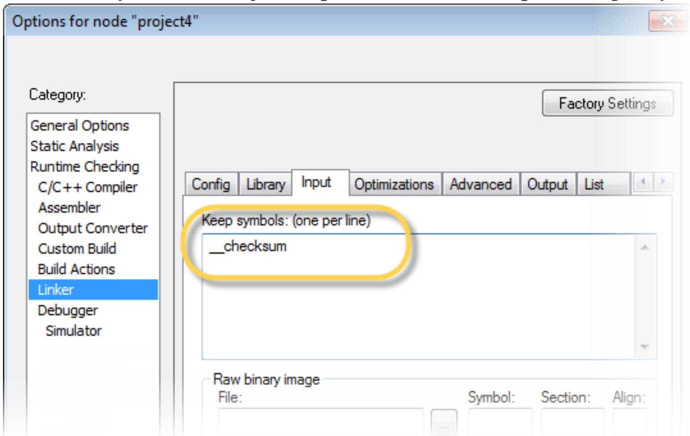
- By creating a global C/C++ or assembler constant symbol with a proper size, residing in a specific section—in this example, `.checksum`
- By using the linker option `--place_holder`.

For example, to allocate a 2-byte space for the symbol `__checksum` in the section `.checksum`, with alignment 4, specify:

```
--place_holder __checksum,2,.checksum,4
```

2 The `.checksum` section will only be included in your application if the section appears to be needed. If the checksum is not needed by the application itself, use the linker option `--keep=__checksum` (or the linker directive `keep`) to force the section to be included.

Alternatively, choose **Project>Options>Linker>Output** and specify `__checksum`:



3 To control the placement of the `.checksum` section, you must modify the linker configuration file. For example, it can look like this (note the handling of the block `CHECKSUM`):

```
define block CHECKSUM    { ro section .checksum };
place in ROM_region  { ro, first block CHECKSUM };
```

Note: It is possible to skip this step, but in that case the `.checksum` section will automatically be placed with other read-only data.

4 When configuring `ielftool` to calculate a checksum, there are some basic choices to make:

- Checksum algorithm

  Choose which checksum algorithm you want to use. In this example, the CRC16 algorithm is used.

- Memory range

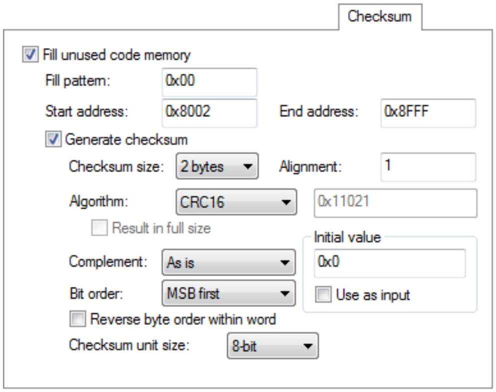
  Using the IDE, you can specify one memory range for which the checksum should be calculated. From the command line, you can specify any ranges.

- Fill pattern

  Specify a fill pattern—typically `0xFF` or `0x00`—for bytes with unknown values. The fill pattern will be used in all checksum ranges.
- Specify an alignment that matches the alignment requirement.

For more information, see *Briefly about checksum calculation*, page 209.

To run `ielftool` from the IDE, choose **Project>Options>Linker>Checksum** and make your settings, for example:



In the simplest case, you can ignore (or leave with default settings) these options: **Alignment**, **Complement**, **Bit order**, **Reverse byte order within word**, and **Checksum unit size**.

To run `ielftool` from the command line, specify the command, for example, like this:

```
ielftool --fill=0x00;0x8002-0x8FFF
--checksum=__checksum:2,crc16;0x8002-0x8FFF sourceFile.out
destinationFile.out
```

Note: `ielftool` needs an unstripped input ELF image. If you use the linker option `--strip`, remove it and use the `ielftool`option `--strip` instead.

The checksum will be created later on when you build your project and will be automatically placed in the specified symbol `__checksum` in the section `.checksum`.

5 You can specify several ranges instead of only one range.

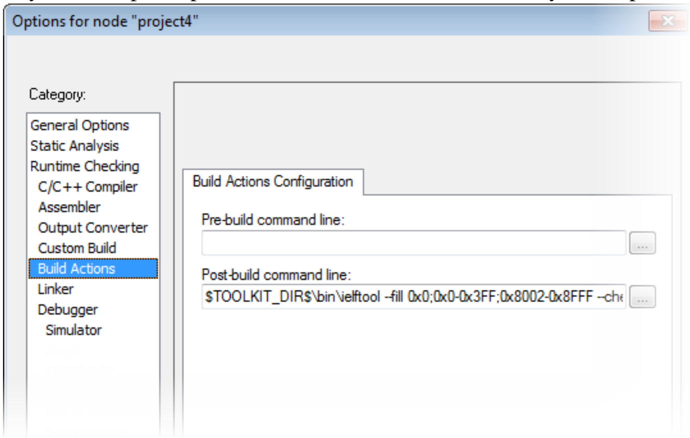
If you are using the IDE, perform these steps:

- Choose **Project>Options>Linker>Checksum** and make sure to deselect **Fill unused code memory**.

- Choose **Project>Options>Build Actions** and specify the ranges together with the rest of the required commands in the **Post-build command line** text field, for example like this:

```
$TOOLKIT_DIR$\bin\ielftool $PROJ_DIR$\debug\exe\output.out
$PROJ_DIR$\debug\exe\output.out
--fill 0x0;0x0-0x3FF;0x8002-0x8FFF
--checksum=__checksum:2,crc16;0x0-0x3FF;0x8002-0x8FFF
```

In your example, replace `output.out` with the name of your output file.



If you are using the command line, specify the ranges, for example like this:

```
ielftool output.out output.out --fill 0x0;0x0-0x3FF;0x8002-0x8FFF
--checksum=__checksum:2,crc16;0x0-0x3FF;0x8002-0x8FFF
```

In your example, replace `output.out` with the name of your output file.

6 Add a function for checksum calculation to your source code. Make sure that the function uses the same algorithm and settings as for the checksum calculated by `ielftool`. For example, a slow variant of the crc16 algorithm but with small memory footprint (in contrast to the fast variant that uses more memory):

```
unsigned short SmallCrc16(uint16_t
 sum,
                         unsigned char *p,
                         unsigned int len)
{
  while (len--)
  {
    int i;
    unsigned char byte = *(p++);

    for (i = 0; i < 8; ++i)
    {
      unsigned long oSum = sum;
      sum <<= 1;
      if (byte & 0x80)
        sum |= 1;
      if (oSum & 0x8000)
        sum ^= 0x1021;
      byte <<= 1;
    }
  }
  return sum;
}
```

You can find the source code for this checksum algorithm in the `rh850\src\linker` directory of your product installation.

7 Make sure that your application also contains a call to the function that calculates the checksum, compares the two checksums, and takes appropriate action if the checksum values do not match.

This code gives an example of how the checksum can be calculated for your application and to be compared with the `ielftool` generated checksum:

```
/* The calculated checksum */

/* Linker generated symbols */
extern unsigned short const __checksum;
extern int __checksum_begin;
extern int __checksum_end;


void TestChecksum()
{
  unsigned short calc = 0;
  unsigned char  zeros[2] = {0, 0};

  /* Run the checksum algorithm */
  calc = SmallCrc16(0,
                  (unsigned char *) &__checksum_begin,
                  ((unsigned char *) &__checksum_end -
                  ((unsigned char *) &__checksum_begin)+1));

  /* Fill the end of the byte sequence with zeros. */
  calc = SmallCrc16(calc, zeros, 2);

  /* Test the checksum */
  if (calc != __checksum)
  {
    printf("Incorrect checksum!\n");
    abort();   /* Failure */
  }

  /* Checksum is correct */
}
```

8 Build your application project and download it.

During the build, `ielftool` creates a checksum and places it in the specified symbol `__checksum` in the section `.checksum`.

9 Choose **Download and Debug** to start the C-SPY debugger.

During execution, the checksum calculated by `ielftool` and the checksum calculated by your application should be identical.

TROUBLESHOOTING CHECKSUM CALCULATION

If the two checksums do not match, there are several possible causes. These are some troubleshooting hints:

- If possible, start with a small example when trying to get the checksums to match.

- Verify that the exact same memory range or ranges are used in both checksum calculations.

  To help you do this, `ielftool` lists the ranges for which the checksum is calculated on `stdout` about the exact addresses that were used and the order in which they were accessed.

- Make sure that all checksum symbols are excluded from all checksum calculations.

  Compare the checksum placement with the checksum range and make sure they do not overlap. You can find information in the **Build** message window after `ielftool` has generated a checksum.

- Verify that the checksum calculations use the same polynomial.
- Verify that the bits in the bytes are processed in the same order in both checksum calculations, from the least to the most significant bit or the other way around. You control this with the **Bit order** option (or from the command line, the `-m` parameter of the `--checksum` option).
- If you are using the small variant of CRC, check whether you need to feed additional bytes into the algorithm.

  The number of zeros to add at the end of the byte sequence must match the size of the checksum, in other words, one zero for a 1-byte checksum, two zeros for a 2-byte checksum, four zeros for a 4-byte checksum, and eight zeros for an 8-byte checksum.

- Any breakpoints in flash memory change the content of the flash. This means that the checksum which is calculated by your application will no longer match the initial checksum calculated by `ielftool`. To make the two checksums match again, you must disable all your breakpoints in flash and any breakpoints set in flash by C-SPY internally. The stack plugin and the debugger option **Run to** both require C-SPY to set breakpoints. Read more about possible breakpoint consumers in the *C-SPY® Debugging Guide for RH850*.
- By default, a symbol that you have allocated in memory by using the linker option `--place_holder` is considered by C-SPY to be of the type `int`. If the size of the checksum is different than the size of an `int`, you can change the display format of the checksum symbol to match its size.

  In the C-SPY **Watch** window, select the symbol and choose **Show As** from the context menu. Choose the display format that matches the size of the checksum symbol.

Register locking

Register locking means that the compiler can be instructed never to touch some processor registers. This can be useful in a number of situations. For example:

- Some parts of a system could be written in assembler language to improve execution speed. These parts could be given dedicated processor registers.
- The register could be used by an operating system, or by other third-party software.

Register locking is performed using the compiler option `--lock_10_regs` on a predefined group of registers. See *--lock_10_regs*, page 273.

Note: The compiler never uses the processor register `R2`.

COMPATIBILITY ISSUES

In general, if two modules are used together in the same application, they should have the same setting for register locking and register constants. The reason for this is that registers that can be locked could also be used as parameter registers when calling functions. In other words, the calling convention will depend on the number of locked registers.

However, because this leads to a situation where suppliers of object files and libraries would be forced to make a choice between either delivering many different prebuilt versions or selecting a few configurations to support, there is a compiler option `--lock_regs_compatibility`. Object files compiled using this option can be linked with object files that lock the same or a fewer number of registers.

To create object files that are compatible with as many options as possible, you should lock ten registers and specify the `--lock_regs_compatibility` option, using a data model that supports short addressing.

Patching symbol definitions using $Super$$ and $Sub$$

Using the `$Sub$$` and `$Super$$` special patterns, you can patch existing symbol definitions in situations where you would otherwise not be able to modify the symbol, for example, when a symbol is located in an external library or in ROM code.

The `$Super$$` special pattern identifies the original unpatched function used for calling the original function directly.

The `$Sub$$` special pattern identifies the new function that is called instead of the original function. You can use the `$Sub$$` special pattern to add processing before or after the original function.

AN EXAMPLE USING THE $SUPER$$ AND $SUB$$ PATTERNS

The following example shows how to use the `$Super$$` and `$Sub$$` patterns to insert a call to the function `ExtraFunc()` before the call to the legacy function `foo()`.

```
extern void ExtraFunc(void);
extern void $Super$$foo(void);

/* this function is called instead of the original foo() */
void $Sub$$foo(void)
{
  ExtraFunc();    /* does some extra setup work */
  $Super$$foo();  /* calls the original foo() function */
                  /* To avoid calling the original foo() function
                   * omit the $Super$$foo(); function call.
                   */
}
```

Efficient coding for embedded applications

- Selecting data types
- Controlling data and function placement in memory
- Controlling compiler optimizations
- Facilitating good code generation

Selecting data types

For efficient treatment of data, you should consider the data types used and the most efficient placement of the variables.

USING EFFICIENT DATA TYPES

The data types you use should be considered carefully, because this can have a large impact on code size and code speed.

- 32-bit integers (`int` etc.) are more efficient than 8- and 16-bit integers (`char` and `short`).
- Floating-point types are inefficient on devices that do not have a floating-point unit. If possible, try to use integers instead. If you must use floating-point types on a device without a floating-point unit, note that 32-bit floating-point numbers are more efficient than 64-bit type doubles.
- Use only bitfields with sizes other than 1 bit when you need to optimize the use of data storage. The generated code is both larger and slower than if non-bitfield integers were used.
- Declaring a pointer parameter to `const` data tells the calling function that the data pointed to will not change.

For information about representation of supported data types, pointers, and structures types, see the chapter *Data representation*.

FLOATING-POINT TYPES

Using floating-point types on a microprocessor without a math coprocessor is inefficient, both in terms of code size and execution speed. Therefore, you should consider replacing code that uses floating-point operations with code that uses integers, because these are more efficient.

The compiler supports two floating-point formats—32 and 64 bits. The 32-bit floating-point type `float` is more efficient in terms of code size and execution speed. However, the 64-bit format `double` supports higher precision and larger numbers.

Unless the application requires the extra precision that 64-bit floating-point numbers give, we recommend using 32-bit floating-point numbers instead. Also, consider replacing code using floating-point operations with code using integers because these are more efficient.

By default, a *floating-point constant* in the source code is treated as being of the type `double`. This can cause innocent-looking expressions to be evaluated in double precision. In the example below `a` is converted from a `float` to a `double`, the `double` constant `1.0` is added and the result is converted back to a `float`:

```
double Test(float a)
{
   return a + 1.0;
}
```

To treat a floating-point constant as a `float` rather than as a `double`, add the suffix `f` to it, for example:

```
double Test(float a)
{
   return a + 1.0f;
}
```

For more information about floating-point types, see *Basic data types—floating-point types*, page 332.

ALIGNMENT OF ELEMENTS IN A STRUCTURE

The RH850 microcontroller requires that when accessing data in memory, the data must be aligned. Each element in a structure must be aligned according to its specified type requirements. This means that the compiler might need to insert *pad bytes* to keep the alignment correct.

There are situations when this can be a problem:

- There are external demands, for example, network communication protocols are usually specified in terms of data types with no padding in between
- You need to save data memory.

For information about alignment requirements, see *Alignment*, page 327.

Use the `#pragma pack` directive for a tighter layout of the structure. The drawback is that each access to an unaligned element in the structure will use more code.

Alternatively, write your own customized functions for *packing* and *unpacking* structures. This is a more portable way, which will not produce any more code apart from your functions. The drawback is the need for two views on the structure data—packed and unpacked.

For more information about the `#pragma pack` directive, see *pack*, page 376.

ANONYMOUS STRUCTS AND UNIONS

When a structure or union is declared without a name, it becomes anonymous. The effect is that its members will only be seen in the surrounding scope.

Example

In this example, the members in the anonymous `union` can be accessed, in function `F`, without explicitly specifying the `union` name:

```
struct S
{
  char mTag;
  union
  {
    long mL;
    float mF;
  };
} St;

void F(void)
{
  St.mL = 5;
}
```

The member names must be unique in the surrounding scope. Having an anonymous `struct` or `union` at file scope, as a global, external, or static variable is also allowed. This could for instance be used for declaring I/O registers, as in this example:

```
__no_init volatile
union
{
  unsigned char IOPORT;
  struct
  {
    unsigned char way: 1;
    unsigned char out: 1;
  };
} @ 0xFFFF8000;



/* The variables are used here. */
void Test(void)
{
  IOPORT = 0;
  way = 1;
  out = 1;
}
```

This declares an I/O register byte `IOPORT` at address `0xFFFF8000`. The I/O register has 2 bits declared, `way` and `out`. Note that both the inner structure and the outer union are anonymous.

Anonymous structures and unions are implemented in terms of objects named after the first field, with a prefix `_A_` to place the name in the implementation part of the namespace. In this example, the anonymous union will be implemented through an object named `_A_IOPORT`.

Controlling data and function placement in memory

The compiler provides different mechanisms for controlling placement of functions and data objects in memory. To use memory efficiently, you should be familiar with these mechanisms and know which one is best suited for different situations. You can use:

- Data models

  By selecting a data model, you can take advantage of the different addressing modes available for the microcontroller and thereby also place data objects in different parts of memory. If possible, use the Small or Medium data model and avoid the Huge data model. For more information, see *Data models*, page 73.

- Data memory attributes

  Using IAR-specific keywords or pragma directives, you can override the default addressing mode, and the default placement of functions and data objects. For more information, see *Using data memory attributes*, page 70.

- The `@` operator and the `#pragma location` directive for absolute placement.

  Using the `@` operator or the `#pragma location` directive, you can place individual global and static variables at absolute addresses. Note that it is not possible to use this notation for absolute placement of individual functions. For more information, see *Data placement at an absolute location*, page 225.

- The `@` operator and the `#pragma location` directive for section placement.

  Using the `@` operator or the `#pragma location` directive, you can place individual functions, variables, and constants in named sections. The placement of these sections can then be controlled by linker directives. For more information, see *Data and function placement in sections*, page 226.

DATA PLACEMENT AT AN ABSOLUTE LOCATION

The `@` operator, alternatively the `#pragma location` directive, can be used for placing global and static variables at absolute addresses.

To place a variable at an absolute address, the argument to the `@` operator and the `#pragma location` directive should be a literal number, representing the actual address.

Note: All declarations of `__no_init` variables placed at an absolute address are *tentative definitions*. Tentatively defined variables are only kept in the output from the compiler if they are needed in the module being compiled. Such variables will be defined in all modules in which they are used, which will work as long as they are defined in the same way. The recommendation is to place all such declarations in header files that are included in all modules that use the variables.

Other variables placed at an absolute address use the normal distinction between declaration and definition. For these variables, you must provide the definition in only one module, normally with an initializer. Other modules can refer to the variable by using an `extern` declaration, with or without an explicit address.

Examples

In this example, a `__no_init` declared variable is placed at an absolute address. This is useful for interfacing between multiple processes, applications, etc:

```
__no_init volatile char alpha @ 0x1000;/* OK */
```

The next example contains two `const` declared objects. The first one is not initialized, and the second one is initialized to a specific value. (The first case is useful for configuration parameters, because they are accessible from an external interface.) Both objects are placed in ROM. Note that in the second case, the compiler is not obliged to actually read from the variable, because the value is known.

```
#pragma location=0x1004
__no_init const int beta;              /* OK */

const int gamma @ 0x1008 = 3;          /* OK */
```

In the first case, the value is not initialized by the compiler—the value must be set by other means. The typical use is for configurations where the values are loaded to ROM separately, or for special function registers that are read-only.

C++ considerations

In C++, module scoped `const` variables are static (module local), whereas in C they are global. This means that each module that declares a certain `const` variable will contain a separate variable with this name. If you link an application with several such modules all containing (via a header file), for instance, the declaration:

```
volatile const __no_init int x @ 0x100;        /* Bad in C++ */
```

the linker will report that more than one variable is located at address `0x100`.

To avoid this problem and make the process the same in C and C++, you should declare these variables `extern`, for example:

```
/* The extern keyword makes x public. */
extern volatile const __no_init int x @ 0x100;
```

Note: C++ static member variables can be placed at an absolute address just like any other static variable.

DATA AND FUNCTION PLACEMENT IN SECTIONS

The following method can be used for placing data or functions in named sections other than default:

- The `@` operator, alternatively the `#pragma location` directive, can be used for placing individual variables or individual functions in named sections. The named section can either be a predefined section, or a user-defined section.
- The `--section` option can be used for placing variables and functions, which are parts of the whole compilation unit, in named sections.

C++ static member variables can be placed in named sections just like any other static variable.

If you use your own sections, in addition to the predefined sections, the sections must also be defined in the linker configuration file.

Note: Take care when explicitly placing a variable or function in a predefined section other than the one used by default. This is useful in some situations, but incorrect placement can result in anything from error messages during compilation and linking to a malfunctioning application. Carefully consider the circumstances—there might be strict requirements on the declaration and use of the function or variable.

The location of the sections can be controlled from the linker configuration file.

For more information about sections, see the chapter *Section reference*.

Examples of placing variables in named sections

In the following examples, a data object is placed in a user-defined section. If no memory attribute is specified, the variable will, like any other variable, be treated as if it is located in the default memory. Note that you must as always ensure that the section is placed in the appropriate memory area when linking.

```
__no_init int alpha @ "MY_NOINIT";      /* OK */

#pragma location="MY_CONSTANTS"
const int beta = 42;                    /* OK */

const int gamma @ "MY_CONSTANTS" = 17;  /* OK */
int theta @ "MY_ZEROS";                 /* OK */
int phi @ "MY_INITED" = 4711;           /* OK */
```

The linker will normally arrange for the correct type of initialization for each variable. If you want to control or suppress automatic initialization, you can use the `initialize` and `do not initialize` directives in the linker configuration file.

As usual, you can use memory attributes to select a memory for the variable. Note that you must as always ensure that the section is placed in the appropriate memory area when linking.

```
__brel __no_init int alpha @ "MY_BREL_NOINIT";/* Placed in
                                                     brel*/
```

Examples of placing functions in named sections

```
void f(void) @ "MY_FUNCTIONS";

void g(void) @ "MY_FUNCTIONS"
{
}

#pragma location="MY_FUNCTIONS"
void h(void);
```

Controlling compiler optimizations

The compiler performs many transformations on your application to generate the best possible code. Examples of such transformations are storing values in registers instead of memory, removing superfluous code, reordering computations in a more efficient order, and replacing arithmetic operations by cheaper operations.

The linker should also be considered an integral part of the compilation system, because some optimizations are performed by the linker. For instance, all unused functions and variables are removed and not included in the final output.

SCOPE FOR PERFORMED OPTIMIZATIONS

You can decide whether optimizations should be performed on your whole application or on individual files. By default, the same types of optimizations are used for an entire project, but you should consider using different optimization settings for individual files. For example, put code that must execute quickly into a separate file and compile it for minimal execution time, and the rest of the code for minimal code size. This will give a small program, which is still fast enough where it matters.

You can also exclude individual functions from the performed optimizations. The `#pragma optimize` directive allows you to either lower the optimization level, or specify another type of optimization to be performed. See *optimize*, page 375, for information about the pragma directive.

MULTI-FILE COMPILATION UNITS

In addition to applying different optimizations to different source files or even functions, you can also decide what a compilation unit consists of—one or several source code files.

By default, a compilation unit consists of one source file, but you can also use multi-file compilation to make several source files in a compilation unit. The advantage is that interprocedural optimizations such as inlining, cross call, and cross jump have more source code to work on. Ideally, the whole application should be compiled as one compilation unit. However, for large applications this is not practical because of resource restrictions on the host computer. For more information, see *--mfc*, page 275.

Note: Only one object file is generated, and therefore all symbols will be part of that object file.

If the whole application is compiled as one compilation unit, it is useful to make the compiler also discard unused public functions and variables before the interprocedural optimizations are performed. Doing this limits the scope of the optimizations to functions and variables that are actually used. For more information, see *--discard_unused_publics*, page 265.

OPTIMIZATION LEVELS

The compiler supports different levels of optimizations. This table lists optimizations that are typically performed on each level:

Optimization level	Description
None (Best debug support)	Variables live through their entire scope Dead code elimination Redundant label elimination Redundant branch elimination
Low	Same as above but variables only live for as long as they are needed, not necessarily through their entire scope
Medium	Same as above, and: Live-dead analysis and optimization Code hoisting Register content analysis and optimization Loop optimization Common subexpression elimination Static clustering
High (Balanced)	Same as above, and: Peephole optimization Cross jumping Instruction scheduling (when optimizing for speed or balanced) Cross call (when optimizing for size or balanced) Loop unrolling Function inlining Code motion Type-based alias analysis

Table 21: Compiler optimization levels

Note: Some of the performed optimizations can be individually enabled or disabled. For more information, see *Fine-tuning enabled transformations*, page 230.

A high level of optimization might result in increased compile time, and will also most likely make debugging more difficult, because it is less clear how the generated code relates to the source code. For example, at the low, medium, and high optimization levels, variables do not live through their entire scope, which means processor registers used for storing variables can be reused immediately after they were last used. Due to this, the C-SPY **Watch** window might not be able to display the value of the variable throughout its scope, or even occasionally display an incorrect value. At any time, if you experience difficulties when debugging your code, try lowering the optimization level.

SPEED VERSUS SIZE

At the high optimization level, the compiler balances between size and speed optimizations. However, it is possible to fine-tune the optimizations explicitly for either size or speed. They only differ in what thresholds that are used—speed will trade size for speed, whereas size will trade speed for size.

If you use the optimization level High speed, the `--no_size_constraints` compiler option relaxes the normal restrictions for code size expansion and enables more aggressive optimizations.

You can choose an optimization goal for each module, or even individual functions, using command line options and pragma directives (see *-O*, page 283 and *optimize*, page 375). For a small embedded application, this makes it possible to achieve acceptable speed performance while minimizing the code size: Typically, only a few places in the application need to be fast, such as the most frequently executed inner loops, or the interrupt handlers.

Rather than compiling the whole application with High (Balanced) optimization, you can use High (Size) in general, but override this to get High (Speed) optimization only for those functions where the application needs to be fast.

Note: Because of the unpredictable way in which different optimizations interact, where one optimization can enable other optimizations, sometimes a function becomes smaller when compiled with High (Speed) optimization than if High (Size) is used. Also, using multi-file compilation (see *--mfc*, page 275) can enable many optimizations to improve both speed and size performance. It is recommended that you experiment with different optimization settings so that you can pick the best ones for your project.

FINE-TUNING ENABLED TRANSFORMATIONS

At each optimization level you can disable some of the transformations individually. To disable a transformation, use either the appropriate option, for instance the command line option `--no_inline`, alternatively its equivalent in the IDE **Function inlining**, or the `#pragma optimize` directive. These transformations can be disabled individually:

- Common subexpression elimination
- Loop unrolling
- Function inlining
- Code motion
- Type-based alias analysis
- Static clustering
- Cross call
- Instruction scheduling.

Common subexpression elimination

Redundant re-evaluation of common subexpressions is by default eliminated at optimization levels Medium and High. This optimization normally reduces both code size and execution time. However, the resulting code might be difficult to debug.

Note: This option has no effect at optimization levels None and Low.

For more information about the command line option, see --*no_cse*, page 277.

Loop unrolling

Loop unrolling means that the code body of a loop, whose number of iterations can be determined at compile time, is duplicated. Loop unrolling reduces the loop overhead by amortizing it over several iterations.

This optimization is most efficient for smaller loops, where the loop overhead can be a substantial part of the total loop body.

Loop unrolling, which can be performed at optimization level High, normally reduces execution time, but increases code size. The resulting code might also be difficult to debug.

The compiler heuristically decides which loops to unroll. Only relatively small loops where the loop overhead reduction is noticeable will be unrolled. Different heuristics are used when optimizing for speed, size, or when balancing between size and speed.

Note: This option has no effect at optimization levels None, Low, and Medium.

For information about the related pragma directive, see *unroll*, page 382.

To disable loop unrolling, use the command line option `--no_unroll`, see --*no_unroll*, page 282.

Function inlining

Function inlining means that a function, whose definition is known at compile time, is integrated into the body of its caller to eliminate the overhead of the call. This optimization normally reduces execution time, but might increase the code size.

For more information, see *Inlining functions*, page 85.

To disable function inlining, use the command line option `--no_inline`, see --*no_inline*, page 278.

Code motion

Evaluation of loop-invariant expressions and common subexpressions are moved to avoid redundant re-evaluation. This optimization, which is performed at optimization level Medium and above, normally reduces code size and execution time. The resulting code might however be difficult to debug.

Note: This option has no effect at optimization levels below Medium.

For more information about the command line option, see *--no_code_motion*, page 277.

Type-based alias analysis

When two or more pointers reference the same memory location, these pointers are said to be *aliases* for each other. The existence of aliases makes optimization more difficult because it is not necessarily known at compile time whether a particular value is being changed.

Type-based alias analysis optimization assumes that all accesses to an object are performed using its declared type or as a `char` type. This assumption lets the compiler detect whether pointers can reference the same memory location or not.

Type-based alias analysis is performed at optimization level High. For application code conforming to standard C or C++ application code, this optimization can reduce code size and execution time. However, non-standard C or C++ code might result in the compiler producing code that leads to unexpected behavior. Therefore, it is possible to turn this optimization off.

Note: This option has no effect at optimization levels None, Low, and Medium.

For more information about the command line option, see *--no_tbaa*, page 280.

Example

```
short F(short *p1, long *p2)
{
  *p2 = 0;
  *p1 = 1;
  return *p2;
}
```

With type-based alias analysis, it is assumed that a write access to the `short` pointed to by `p1` cannot affect the `long` value that `p2` points to. Therefore, it is known at compile time that this function returns 0. However, in non-standard-conforming C or C++ code these pointers could overlap each other by being part of the same union. If you use explicit casts, you can also force pointers of different pointer types to point to the same memory location.

Static clustering

When static clustering is enabled, static and global variables that are defined within the same module are arranged so that variables that are accessed in the same function are stored close to each other. This makes it possible for the compiler to use the same base pointer for several accesses.

Note: This option has no effect at optimization levels None and Low.

For more information about the command line option, see *--no_clustering*, page 276.

Cross call

Common code sequences are extracted to local subroutines. This optimization, which is performed at optimization level High, can reduce code size, sometimes dramatically, on behalf of execution time and stack size. The resulting code might however be difficult to debug. This optimization cannot be disabled using the `#pragma optimize` directive.

Note: This option has no effect at optimization levels None, Low, and Medium, unless the option `--do_cross_call` is used.

For more information about related command line options, see *--no_cross_call*, page 277.

Instruction scheduling

The compiler features an instruction scheduler to increase the performance of the generated code. To achieve that goal, the scheduler rearranges the instructions to minimize the number of pipeline stalls emanating from resource conflicts within the microprocessor. Note that not all cores benefit from scheduling. The resulting code might be difficult to debug.

Note: This option has no effect at optimization levels None, Low and Medium.

For more information about the command line option, see *--no_scheduling*, page 279.

Facilitating good code generation

This section contains hints on how to help the compiler generate good code:

WRITING OPTIMIZATION-FRIENDLY SOURCE CODE

The following is a list of programming techniques that will, when followed, enable the compiler to better optimize the application.

- Local variables—auto variables and parameters—are preferred over static or global variables. The reason is that the optimizer must assume, for example, that called functions can modify non-local variables. When the life spans for local variables end, the previously occupied memory can then be reused. Globally declared variables will occupy data memory during the whole program execution.
- Avoid taking the address of local variables using the `&` operator. This is inefficient for two main reasons. First, the variable must be placed in memory, and therefore cannot be placed in a processor register. This results in larger and slower code. Second, the optimizer can no longer assume that the local variable is unaffected over function calls.
- Module-local variables—variables that are declared static—are preferred over global variables (non-static). Also, avoid taking the address of frequently accessed static variables.
- The compiler is capable of inlining functions, see *Function inlining*, page 231. To maximize the effect of the inlining transformation, it is good practice to place the definitions of small functions called from more than one module in the header file rather than in the implementation file. Alternatively, you can use multi-file compilation. For more information, see *Multi-file compilation units*, page 228.
- Avoid using inline assembler without operands and clobbered resources. Instead, use SFRs or intrinsic functions if available. Otherwise, use inline assembler *with* operands and clobbered resources or write a separate module in assembler language. For more information, see *Mixing C and assembler*, page 161.
- Set the heap size to a value which accommodates the needs of the standard I/O buffer, for example to 1 Kbyte.

SAVING STACK SPACE AND RAM MEMORY

The following is a list of programming techniques that save memory and stack space:

- If stack space is limited, avoid long call chains and recursive functions.
- Avoid using large non-scalar types, such as structures, as parameters or return type. To save stack space, you should instead pass them as pointers or, in C++, as references.

FUNCTION PROTOTYPES

It is possible to declare and define functions using one of two different styles:

- Prototyped

- Kernighan & Ritchie C (K&R C)

Both styles are valid C, however it is strongly recommended to use the prototyped style, and provide a prototype declaration for each public function in a header that is included both in the compilation unit defining the function and in all compilation units using it.

The compiler will not perform type checking on parameters passed to functions declared using K&R style. Using prototype declarations will also result in more efficient code in some cases, as there is no need for type promotion for these functions.

To make the compiler require that all function definitions use the prototyped style, and that all public functions have been declared before being defined, use the **Project>Options>C/C++ Compiler>Language 1>Require prototypes** compiler option (`--require_prototypes`).

Prototyped style

In prototyped function declarations, the type for each parameter must be specified.

```
int Test(char, int); /* Declaration */

int Test(char ch, int i) /* Definition */
{
  return i + ch;
}
```

Kernighan & Ritchie style

In K&R style—pre-Standard C—it is not possible to declare a function prototyped. Instead, an empty parameter list is used in the function declaration. Also, the definition looks different.

For example:

```
int Test();     /* Declaration */

int Test(ch, i) /* Definition */
char ch;
int i;
{
  return i + ch;
}
```

INTEGER TYPES AND BIT NEGATION

In some situations, the rules for integer types and their conversion lead to possibly confusing behavior. Things to look out for are assignments or conditionals (test expressions) involving types with different size, and logical operations, especially bit negation. Here, *types* also includes types of constants.

In some cases there might be warnings—for example, for constant conditional or pointless comparison—in others just a different result than what is expected. Under certain circumstances the compiler might warn only at higher optimizations, for example, if the compiler relies on optimizations to identify some instances of constant conditionals. In this example, an 8-bit character, a 32-bit integer, and two's complement is assumed:

```
void F1(unsigned char c1)
{
  if (c1 == ~0x80)
    ;
}
```

Here, the test is always false. On the right hand side, `0x80` is `0x00000080`, and `~0x00000080` becomes `0xFFFFFF7F`. On the left hand side, `c1` is an 8-bit unsigned character in the range 0–255, which can never be equal to `0xFFFFFF7F`. Furthermore, it cannot be negative, which means that the integral promoted value can never have the topmost 8 bits set.

PROTECTING SIMULTANEOUSLY ACCESSED VARIABLES

Variables that are accessed asynchronously, for example, by interrupt routines or by code executing in separate threads, must be properly marked and have adequate protection. The only exception to this is a variable that is always *read-only*.

To mark a variable properly, use the `volatile` keyword. This informs the compiler, among other things, that the variable can be changed from other threads. The compiler will then avoid optimizing on the variable—for example, keeping track of the variable in registers—will not delay writes to it, and be careful accessing the variable only the number of times given in the source code.

For sequences of accesses to variables that you do not want to be interrupted, use the `__monitor` keyword. This must be done for both write *and* read sequences, otherwise you might end up reading a partially updated variable. Accessing a small-sized `volatile` variable can be an atomic operation, but you should not rely on it unless you continuously study the compiler output. It is safer to use the `__monitor` keyword to ensure that the sequence is an atomic operation. For more information, see *__monitor*, page 349.

For more information about the `volatile` type qualifier and the rules for accessing volatile objects, see *Declaring objects volatile*, page 337.

ACCESSING SPECIAL FUNCTION REGISTERS

Specific header files for several RH850 devices are included in the IAR product installation. The header files are named `iodevice.h` and define the processor-specific special function registers (SFRs).

Note: Each header file contains one section used by the compiler, and one section used by the assembler.

SFRs with bitfields are declared in the header file:

```
__no_init volatile union
{
  unsigned short mwctl2;
  struct
  {
    unsigned short edr: 1;
    unsigned short edw: 1;
    unsigned short lee: 2;
    unsigned short lemd: 2;
    unsigned short lepl: 2;
  } mwctl2bit;
} @ 0xFFFF8000;


/* By including the appropriate include file in your code,
 * it is possible to access either the whole register or any
 * individual bit (or bitfields) from C code as follows.
 */

void Test()
{
  /* Whole register access */
  mwctl2 = 0x1234;

  /* Bitfield accesses */
  mwctl2bit.edw  = 1;
  mwctl2bit.lepl = 3;
}
```

You can also use the header files as templates when you create new header files for other RH850 devices. For information about the @ operator, see *Controlling data and function placement in memory*, page 224.

PASSING VALUES BETWEEN C AND ASSEMBLER OBJECTS

The following example shows how you in your C source code can use inline assembler to set and get values from a special purpose register:

```
static unsigned long get_EIPSW(void)
{
  static unsigned long value;
  asm volatile("stsr EIPSW,%0" : : "=r"(value));
  return value;
}

static void set_EIPSW(unsigned long value)
{
  asm volatile("ldsr %0,EIPSW" : "r"(value));
}
```

The general purpose register is used for getting and setting the value of the special purpose register `EIPSW`. The same method can be used also for accessing other special purpose registers and specific instructions.

To read more about inline assembler, see *Inline assembler*, page 162.

NON-INITIALIZED VARIABLES

Normally, the runtime environment will initialize all global and static variables when the application is started.

The compiler supports the declaration of variables that will not be initialized, using the `__no_init` type modifier. They can be specified either as a keyword or using the `#pragma object_attribute` directive. The compiler places such variables in a separate section, according to the specified memory keyword.

For `__no_init`, the `const` keyword implies that an object is read-only, rather than that the object is stored in read-only memory. It is not possible to give a `__no_init` object an initial value.

Variables declared using the `__no_init` keyword could, for example, be large input buffers or mapped to special RAM that keeps its content even when the application is turned off.

For more information, see *__no_init*, page 352.

Note: To use this keyword, language extensions must be enabled, see *-e*, page 267. For more information, see *object_attribute*, page 374.

Part 2. Reference information

This part of the *IAR C/C++ Development Guide for RH850* contains these chapters:

- External interface details
- Compiler options
- Linker options
- Data representation
- Extended keywords
- Pragma directives
- Intrinsic functions
- The preprocessor
- C/C++ standard library functions
- The linker configuration file
- Section reference
- The stack usage control file
- IAR utilities
- Implementation-defined behavior for Standard C++
- Implementation-defined behavior for Standard C
- Implementation-defined behavior for C89.

External interface details

- Invocation syntax
- Include file search procedure
- Compiler output
- ILINK output
- Text encodings
- Reserved identifiers
- Diagnostics

Invocation syntax

You can use the compiler and linker either from the IDE or from the command line. See the *IDE Project Management and Building Guide for RH850* for information about using the build tools from the IDE.

COMPILER INVOCATION SYNTAX

The invocation syntax for the compiler is:

```
iccrh850 [options] [sourcefile] [options]
```

For example, when compiling the source file `prog.c`, use this command to generate an object file with debug information:

```
iccrh850 prog.c --debug
```

The source file can be a C or C++ file, typically with the filename extension `c` or `cpp`, respectively. If no filename extension is specified, the file to be compiled must have the extension `c`.

Generally, the order of options on the command line, both relative to each other and to the source filename, is not significant. There is, however, one exception: when you use the `-I` option, the directories are searched in the same order as they are specified on the command line.

If you run the compiler from the command line without any arguments, the compiler version number and all available options including brief descriptions are directed to `stdout` and displayed on the screen.

ILINK INVOCATION SYNTAX

The invocation syntax for ILINK is:

```
ilinkrh850 [arguments]
```

Each argument is either a command-line option, an object file, or a library.

For example, when linking the object file `prog.o`, use this command:

```
ilinkrh850 prog.o --config configfile
```

If no filename extension is specified for the linker configuration file, the configuration file must have the extension `icf`.

Generally, the order of arguments on the command line is not significant. There is, however, one exception: when you supply several libraries, the libraries are searched in the same order that they are specified on the command line. The default libraries are always searched last.

The output executable image will be placed in a file named `a.out`, unless the `-o` option is used.

If you run ILINK from the command line without any arguments, the ILINK version number and all available options including brief descriptions are directed to `stdout` and displayed on the screen.

PASSING OPTIONS

There are three different ways of passing options to the compiler and to ILINK:

- Directly from the command line

  Specify the options on the command line after the `iccrh850` or `ilinkrh850` commands, see *Invocation syntax*, page 241.
- Via environment variables

  The compiler and linker automatically append the value of the environment variables to every command line, see *Environment variables*, page 243.
- Via a text file, using the `-f` option, see *-f*, page 269.

For general guidelines for the option syntax, an options summary, and a detailed description of each option, see the chapter *Compiler options*.

ENVIRONMENT VARIABLES

These environment variables can be used with the compiler:

Environment variable	Description
`C_INCLUDE`	Specifies directories to search for include files, for example: `C_INCLUDE=c:\my_programs\embedded workbench .n\rh850\inc;c:\headers`
`QCCRH850`	Specifies command line options, for example: `QCCRH850=-lA asm.lst`

Table 22: Compiler environment variables

This environment variable can be used with ILINK:

Environment variable	Description
`ILINKRH850_CMD_LINE`	Specifies command line options, for example: `ILINKRH850_CMD_LINE=--config full.icf --silent`

Table 23: ILINK environment variables

Include file search procedure

This is a detailed description of the compiler's `#include` file search procedure:

- The string found between the `""` and `<>` in the `#include` directive is used verbatim as a source file name.
- If the name of the `#include` file is an absolute path specified in angle brackets or double quotes, that file is opened.
- If the compiler encounters the name of an `#include` file in angle brackets, such as:

  ```
  #include <stdio.h>
  ```

  it searches these directories for the file to include:

  1 The directories specified with the `-I` option, in the order that they were specified, see *-I*, page 272.

  2 The directories specified using the `C_INCLUDE` environment variable, if any, see *Environment variables*, page 243.

  3 The automatically set up library system include directories. See *--dlib_config*, page 266.

- If the compiler encounters the name of an `#include` file in double quotes, for example:

  ```
  #include "vars.h"
  ```

it searches the directory of the source file in which the `#include` statement occurs, and then performs the same sequence as for angle-bracketed filenames.

If there are nested `#include` files, the compiler starts searching the directory of the file that was last included, iterating upwards for each included file, searching the source file directory last. For example:

```
src.c in directory dir\src
  #include "src.h"
  ...
src.h in directory dir\include
  #include "config.h"
  ...
```

When `dir\exe` is the current directory, use this command for compilation:

```
iccrh850 ..\src\src.c -I..\include -I..\debugconfig
```

Then the following directories are searched in the order listed below for the file `config.h`, which in this example is located in the `dir\debugconfig` directory:

`dir\include`	Current file is `src.h`.
`dir\src`	File including current file (`src.c`).
`dir\include`	As specified with the first `-I` option.
`dir\debugconfig`	As specified with the second `-I` option.

Use angle brackets for standard header files, like `stdio.h`, and double quotes for files that are part of your application.

Note: Both `\` and `/` can be used as directory delimiters.

For more information, see *Overview of the preprocessor*, page 403.

Compiler output

The compiler can produce the following output:

- A linkable object file

  The object files produced by the compiler use the industry-standard format ELF. By default, the object file has the filename extension `o`.
- Optional list files

  Various kinds of list files can be specified using the compiler option `-l`, see *-l*, page 272. By default, these files will have the filename extension `lst`.

- Optional preprocessor output files

  A preprocessor output file is produced when you use the `--preprocess` option. The file will have the filename extension `i`, by default.

- Diagnostic messages

  Diagnostic messages are directed to the standard error stream and displayed on the screen, and printed in an optional list file. For more information about diagnostic messages, see *Diagnostics*, page 248.

- Error return codes

  These codes provide status information to the operating system which can be tested in a batch file, see *Error return codes*, page 245.

- Size information

  Information about the generated amount of bytes for functions and data for each memory is directed to the standard output stream and displayed on the screen. Some of the bytes might be reported as *shared*.

  Shared objects are functions or data objects that are shared between modules. If any of these occur in more than one module, only one copy is retained. For example, in some cases inline functions are not inlined, which means that they are marked as shared, because only one instance of each function will be included in the final application. This mechanism is sometimes also used for compiler-generated code or data not directly associated with a particular function or variable, and when only one instance is required in the final application.

ERROR RETURN CODES

The compiler and linker return status information to the operating system that can be tested in a batch file.

These command line error codes are supported:

Code	Description
0	Compilation or linking successful, but there might have been warnings.
1	Warnings were produced and the option `--warnings_affect_exit_code` was used.
2	Errors occurred.
3	Fatal errors occurred, making the tool abort.
4	Internal errors occurred, making the tool abort.

Table 24: Error return codes

ILINK output

ILINK can produce the following output:

- An absolute executable image

  The final output produced by the IAR ILINK Linker is an absolute object file containing the executable image that can be put into an EPROM, downloaded to a hardware emulator, or executed on your PC using the IAR C-SPY Debugger Simulator. By default, the file has the filename extension `out`. The output format is always in ELF, which optionally includes debug information in the DWARF format.
- Optional logging information

  During operation, ILINK logs its decisions on `stdout`, and optionally to a file. For example, if a library is searched, whether a required symbol is found in a library module, or whether a module will be part of the output. Timing information for each ILINK subsystem is also logged.
- Optional map files

  A linker map file—containing summaries of linkage, runtime attributes, memory, and placement, as well as an entry list— can be generated by the ILINK option `--map`, see *--map*, page 313. By default, the map file has the filename extension `map`.
- Diagnostic messages

  Diagnostic messages are directed to `stderr` and displayed on the screen, as well as printed in the optional map file. For more information about diagnostic messages, see *Diagnostics*, page 248.
- Error return codes

  ILINK returns status information to the operating system which can be tested in a batch file, see *Error return codes*, page 245.
- Size information about used memory and amount of time

  Information about the generated amount of bytes for functions and data for each memory is directed to `stdout` and displayed on the screen.

Text encodings

Text files read or written by IAR tools can use a variety of text encodings:

- Raw

  This is a backward-compatibility mode for C/C++ source files. Only 7-bit ASCII characters can be used in symbol names. Other characters can only be used in comments, literals, etc. This is the default source file encoding if there is no Byte Order Mark (BOM).

- The system default locale

  The locale that you have configured your Windows OS to use.
- UTF-8

  Unicode encoded as a sequence of 8-bit bytes, with or without a Byte Order Mark.
- UTF-16

  Unicode encoded as a sequence of 16-bit words using a big-endian or little-endian representation. These files always start with a Byte Order Mark.

In any encoding other than Raw, you can use Unicode characters of the appropriate kind (alphabetic, numeric, etc) in the names of symbols.

When an IAR tool reads a text file with a Byte Order Mark, it will use the appropriate Unicode encoding, regardless of the any options set for input file encoding.

For source files without a Byte Order Mark, the compiler will use the Raw encoding, unless you specify the compiler option `--source_encoding`. See --*source_encoding*, page 288.

For other text input files, like the extended command line (`.xcl` files), without a Byte Order Mark, the IAR tools will use the system default locale unless you specify the compiler option `--utf8_text_in`, in which case UTF-8 will be used. See --*utf8_text_in*, page 292.

For compiler list files and preprocessor output, the same encoding as the main source file will be used by default. Other tools that generate text output will use the UTF-8 encoding by default. You can change this by using the compiler options `--text_out` and `--no_bom`. See --*text_out*, page 290 and --*no_bom*, page 276.

CHARACTERS AND STRING LITERALS

When you compile source code, characters (*x*) and string literals (*xx*) are handled as follows:

`'x', "xx"`	Characters in untyped character and string literals are copied verbatim, using the same encoding as in the source file.
`u8"xx"`	Characters in UTF-8 string literals are converted to UTF-8.
`u'x', u"xx"`	Characters in UTF-16 character and string literals are converted to UTF-16.
`U'x', U"xx"`	Characters in UTF-32 character and string literals are converted to UTF-32.
`L'x', L"xx"`	Characters in wide character and string literals are converted to UTF-32.

Reserved identifiers

Some identifiers are reserved for use by the implementation. Some of the more important identifiers that the C/C++ standards reserve for any use are:

- Identifiers that contain a double underscore (`__`)
- Identifiers that begin with an underscore followed by an uppercase letter

In addition to this, the IAR tools reserve for any use:

- Identifiers that contain a double dollar sign (`$$`)
- Identifiers that contain a question mark (`?`)

More specific reservations are in effect in particular circumstances, see the C/C++ standards for more information.

Diagnostics

This section describes the format of the diagnostic messages and explains how diagnostic messages are divided into different levels of severity.

MESSAGE FORMAT FOR THE COMPILER

All diagnostic messages are issued as complete, self-explanatory messages. A typical diagnostic message from the compiler is produced in the form:

filename,*linenumber* *level*[*tag*]: *message*

with these elements:

filename	The name of the source file in which the issue was encountered
linenumber	The line number at which the compiler detected the issue
level	The level of seriousness of the issue
tag	A unique tag that identifies the diagnostic message
message	An explanation, possibly several lines long

Diagnostic messages are displayed on the screen, as well as printed in the optional list file.

Use the option `--diagnostics_tables` to list all possible compiler diagnostic messages.

MESSAGE FORMAT FOR THE LINKER

All diagnostic messages are issued as complete, self-explanatory messages. A typical diagnostic message from ILINK is produced in the form:

`level[tag]: message`

with these elements:

level	The level of seriousness of the issue
tag	A unique tag that identifies the diagnostic message
message	An explanation, possibly several lines long

Diagnostic messages are displayed on the screen and printed in the optional map file.

Use the option `--diagnostics_tables` to list all possible linker diagnostic messages.

SEVERITY LEVELS

The diagnostic messages are divided into different levels of severity:

Remark

A diagnostic message that is produced when the compiler or linker finds a construct that can possibly lead to erroneous behavior in the generated code. Remarks are by default not issued, but can be enabled, see *--remarks*, page 287.

Warning

A diagnostic message that is produced when the compiler or linker finds a potential problem which is of concern, but which does not prevent completion of the compilation or linking. Warnings can be disabled by use of the command line option `--no_warnings`, see *--no_warnings*, page 282.

Error

A diagnostic message that is produced when the compiler or linker finds a serious error. An error will produce a non-zero exit code.

Fatal error

A diagnostic message produced when the compiler finds a condition that not only prevents code generation, but also makes further processing pointless. After the message is issued, compilation terminates. A fatal error will produce a non-zero exit code.

SETTING THE SEVERITY LEVEL

The diagnostic messages can be suppressed or the severity level can be changed for all diagnostics messages, except for fatal errors and some of the regular errors.

For information about the compiler options that are available for setting severity levels, see the chapter *Compiler options*.

For information about the pragma directives that are available for setting severity levels for the compiler, see the chapter *Pragma directives*.

INTERNAL ERROR

An internal error is a diagnostic message that signals that there was a serious and unexpected failure due to a fault in the compiler or linker. It is produced using this form:

```
Internal error: message
```

where `message` is an explanatory message. If internal errors occur, they should be reported to your software distributor or IAR Systems Technical Support. Include enough information to reproduce the problem, typically:

- The product name
- The version number of the compiler or of ILINK, which can be seen in the header of the list or map files generated by the compiler or by ILINK, respectively
- Your license number
- The exact internal error message text
- The files involved of the application that generated the internal error
- A list of the options that were used when the internal error occurred.

Compiler options

- Options syntax
- Summary of compiler options
- Descriptions of compiler options

Options syntax

Compiler options are parameters you can specify to change the default behavior of the compiler. You can specify options from the command line—which is described in more detail in this section—and from within the IDE.

See the online help system for information about the compiler options available in the IDE and how to set them.

TYPES OF OPTIONS

There are two *types of names* for command line options, *short* names and *long* names. Some options have both.

- A short option name consists of one character, and it can have parameters. You specify it with a single dash, for example `-e`
- A long option name consists of one or several words joined by underscores, and it can have parameters. You specify it with double dashes, for example `--char_is_signed`.

For information about the different methods for passing options, see *Passing options*, page 242.

RULES FOR SPECIFYING PARAMETERS

There are some general syntax rules for specifying option parameters. First, the rules depending on whether the parameter is *optional* or *mandatory*, and whether the option has a short or a long name, are described. Then, the rules for specifying filenames and directories are listed. Finally, the remaining rules are listed.

Rules for optional parameters

For options with a short name and an optional parameter, any parameter should be specified without a preceding space, for example:

`-O` or `-Oh`

For options with a long name and an optional parameter, any parameter should be specified with a preceding equal sign (=), for example:

`--misrac2004=`*`n`*

Rules for mandatory parameters

For options with a short name and a mandatory parameter, the parameter can be specified either with or without a preceding space, for example:

`-I..\src` or `-I ..\src\`

For options with a long name and a mandatory parameter, the parameter can be specified either with a preceding equal sign (=) or with a preceding space, for example:

```
--diagnostics_tables=MyDiagnostics.lst
```

or

```
--diagnostics_tables MyDiagnostics.lst
```

Rules for options with both optional and mandatory parameters

For options taking both optional and mandatory parameters, the rules for specifying the parameters are:

- For short options, optional parameters are specified without a preceding space
- For long options, optional parameters are specified with a preceding equal sign (=)
- For short and long options, mandatory parameters are specified with a preceding space.

For example, a short option with an optional parameter followed by a mandatory parameter:

```
-lA MyList.lst
```

For example, a long option with an optional parameter followed by a mandatory parameter:

```
--preprocess=n PreprocOutput.lst
```

Rules for specifying a filename or directory as parameters

These rules apply for options taking a filename or directory as parameters:

- Options that take a filename as a parameter can optionally take a file path. The path can be relative or absolute. For example, to generate a listing to the file `List.lst` in the directory `..\listings\`:

  ```
  iccrh850 prog.c -l ..\listings\List.lst
  ```

- For options that take a filename as the destination for output, the parameter can be specified as a path without a specified filename. The compiler stores the output in that directory, in a file with an extension according to the option. The filename will be the same as the name of the compiled source file, unless a different name was specified with the option `-o`, in which case that name is used. For example:

  ```
  iccrh850 prog.c -l ..\listings\
  ```

  The produced list file will have the default name `..\listings\prog.lst`
- The *current directory* is specified with a period (`.`). For example:

  ```
  iccrh850 prog.c -l .
  ```
- `/` can be used instead of `\` as the directory delimiter.
- By specifying `-`, input files and output files can be redirected to the standard input and output stream, respectively. For example:

  ```
  iccrh850 prog.c -l -
  ```

Additional rules

These rules also apply:

- When an option takes a parameter, the parameter cannot start with a dash (-) followed by another character. Instead, you can prefix the parameter with two dashes—this example will create a list file called `-r`:

  ```
  iccrh850 prog.c -l ---r
  ```
- For options that accept multiple arguments of the same type, the arguments can be provided as a comma-separated list (without a space), for example:

  ```
  --diag_warning=Be0001,Be0002
  ```

  Alternatively, the option can be repeated for each argument, for example:

  ```
  --diag_warning=Be0001
  --diag_warning=Be0002
  ```

Summary of compiler options

This table summarizes the compiler command line options:

Command line option	Description
`--allow_misaligned_data_access`	Allows misaligned data accesses
`--allow_volatile_bit_instructions_for_all_sizes`	Permits bit instructions on volatile accesses for all data types.
`--c89`	Specifies the C89 dialect
`--char_is_signed`	Treats `char` as signed

Table 25: Compiler options summary

Command line option	Description
`--char_is_unsigned`	Treats `char` as unsigned
`--core`	Specifies a CPU core
`--c++`	Specifies Standard C++
`-D`	Defines preprocessor symbols
`--data_model`	Specifies the data model
`--debug`	Generates debug information
`--dependencies`	Lists file dependencies
`--deprecated_feature_warnings`	Enables/disables warnings for deprecated features
`--diag_error`	Treats these as errors
`--diag_remark`	Treats these as remarks
`--diag_suppress`	Suppresses these diagnostics
`--diag_warning`	Treats these as warnings
`--diagnostics_tables`	Lists all diagnostic messages
`--discard_unused_publics`	Discards unused public symbols
`--dlib_config`	Uses the system include files for the DLIB library and determines which configuration of the library to use
`--do_explicit_zero_opt_in_named_sections`	For user-named sections, treats explicit initializations to zero as zero initializations
`--double`	Forces the compiler to use 32-bit or 64-bit doubles
`-e`	Enables language extensions
`--enable_8_byte_alignment`	Enables 8-byte alignment for `long long` and `double`
`--enable_restrict`	Enables the Standard C keyword `restrict`
`--enable_saddr_support`	Enables short addressing by locking the `EP` register
`--enum_is_int`	Sets the minimum size on enumeration types
`--error_limit`	Specifies the allowed number of errors before compilation stops
`-f`	Extends the command line
`--f`	Extends the command line, optionally with a dependency.

Table 25: Compiler options summary (Continued)

Command line option	Description
`--fpu`	Enables the floating-point unit and sets the precision
`--generate_interrupt_instrumentation_code`	Enables interrupt logging in the debugger.
`--guard_calls`	Enables guards for function static variable initialization
`--header_context`	Lists all referred source files and header files
`-I`	Specifies include file path
`-l`	Creates a list file
`--lock_10_regs`	Locks ten registers
`--lock_global_pointer_regs`	Reserves 0–5 registers for use as extra global pointer registers
`--lock_regs_compatibility`	Permits different register locking levels
`--macro_positions_in_diagnostics`	Obtains positions inside macros in diagnostic messages
`--max_cost_constexpr_call`	Specifies the limit for `constexpr` evaluation cost
`--max_depth_constexpr_call`	Specifies the limit for `constexpr` recursion depth
`--mfc`	Enables multi-file compilation
`--misrac1998`	Enables error messages specific to MISRA-C:1998. See the *IAR Embedded Workbench® MISRA C:1998 Reference Guide*.
`--misrac2004`	Enables error messages specific to MISRA-C:2004. See the *IAR Embedded Workbench® MISRA C:2004 Reference Guide*.
`--misrac_verbose`	*IAR Embedded Workbench® MISRA C:1998 Reference Guide* or the *IAR Embedded Workbench® MISRA C:2004 Reference Guide*.
`--no_bit_instructions`	Disables the generation of bit instructions
`--no_bom`	Omits the Byte Order Mark for UTF-8 output files
`--no_call_frame_info`	Disables output of call frame information
`--no_clustering`	Disables static clustering optimizations
`--no_code_motion`	Disables code motion optimization

Table 25: Compiler options summary (Continued)

Command line option	Description
--no_cross_call	Disables cross-call optimization
--no_cse	Disables common subexpression elimination
--no_data_model_rt_attribute	Suppresses generation of the data model runtime attribute
--no_fragments	Disables section fragment handling
--no_inline	Disables function inlining
--no_loop	Disables the use of the LOOP instruction
--no_path_in_file_macros	Removes the path from the return value of the symbols __FILE__ and __BASE_FILE__
--no_scheduling	Disables the instruction scheduler
--no_size_constraints	Relaxes the normal restrictions for code size expansion when optimizing for speed.
--no_static_destruction	Disables destruction of C++ static variables at program exit
--no_system_include	Disables the automatic search for system include files
--no_tbaa	Disables type-based alias analysis
--no_typedefs_in_diagnostics	Disables the use of typedef names in diagnostics
--no_uniform_attribute_syntax	Specifies the default syntax rules for IAR type attributes
--no_unroll	Disables loop unrolling
--no_warnings	Disables all warnings
--no_wrap_diagnostics	Disables wrapping of diagnostic messages
--nonportable_path_warnings	Generates a warning when the path used for opening a source header file is not in the same case as the path in the file system.
-O	Sets the optimization level
-o	Sets the object filename. Alias for --output.
--only_stdout	Uses standard output only
--output	Sets the object filename
--pending_instantiations	Sets the maximum number of instantiations of a given C++ template.
--predef_macros	Lists the predefined symbols.

Table 25: Compiler options summary (Continued)

Command line option	Description
`--preinclude`	Includes an include file before reading the source file
`--preprocess`	Generates preprocessor output
`--public_equ`	Defines a global named assembler label
`-r`	Generates debug information. Alias for `--debug`.
`--relaxed_fp`	Relaxes the rules for optimizing floating-point expressions
`--remarks`	Enables remarks
`--require_prototypes`	Verifies that functions are declared before they are defined
`--section`	Changes a section name
`--silent`	Sets silent operation
`--source_encoding`	Specifies the encoding for source files
`--stack_protection`	Enables stack protection
`--strict`	Checks for strict compliance with Standard C/C++
`--system_include_dir`	Specifies the path for system include files
`--text_out`	Specifies the encoding for text output files
`--uniform_attribute_syntax`	Specifies the same syntax rules for IAR type attributes as for `const` and `volatile`
`--use_c++_inline`	Uses C++ inline semantics in C
`--use_paths_as_written`	Use paths as written in debug information
`--use_unix_directory_separators`	Uses `/` as directory separator in paths
`--utf8_text_in`	Uses the UTF-8 encoding for text input files
`--version`	Sends compiler output to the console and then exits.
`--vla`	Enables VLA support
`--warn_about_c_style_casts`	Makes the compiler warn when C-style casts are used in C++ source code
`--warnings_affect_exit_code`	Warnings affect exit code
`--warnings_are_errors`	Warnings are treated as errors

Table 25: Compiler options summary (Continued)

Descriptions of compiler options

The following section gives detailed reference information about each compiler option.

If you use the options page **Extra Options** to specify specific command line options, the IDE does not perform an instant check for consistency problems like conflicting options, duplication of options, or use of irrelevant options.

--allow_misaligned_data_access

Syntax

`--allow_misaligned_data_access`

Description

Use this option to make it possible to access misaligned data objects. The option can be used in conjunction with the `#pragma pack` directive for `structs` with misaligned members.

Typically, using this option is more efficient than a normal access to a packed structure. However, a misaligned access is slower than an aligned access.

See also

#pragma pack, page 376 for more information about using the `#pragma pack` directive.

Project>Options>C/C++ Compiler>Optimizations>Enable misaligned data access

--allow_volatile_bit_instructions_for_all_sizes

Syntax

`--allow_volatile_bit_instructions_for_all_sizes`

Description

By default, bit instructions on volatile accesses will only be generated for 8-bit data types. Specify this option to permit bit instructions on volatile accesses for other data type sizes as well.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--c89

Syntax

`--c89`

Description

Use this option to enable the C89 C dialect instead of Standard C.

Note: This option is mandatory when the MISRA C checking is enabled.

See also *C language overview*, page 187.

Project>Options>C/C++ Compiler>Language 1>C dialect>C89

--char_is_signed

Syntax `--char_is_signed`

Description

By default, the compiler interprets the plain `char` type as unsigned. Use this option to make the compiler interpret the plain `char` type as signed instead. This can be useful when you, for example, want to maintain compatibility with another compiler.

Note: The runtime library is compiled without the `--char_is_signed` option and cannot be used with code that is compiled with this option.

Project>Options>C/C++ Compiler>Language 2>Plain 'char' is

--char_is_unsigned

Syntax `--char_is_unsigned`

Description

Use this option to make the compiler interpret the plain `char` type as unsigned. This is the default interpretation of the plain `char` type.

Project>Options>C/C++ Compiler>Language 2>Plain 'char' is

--core

Syntax `--core={g3k|g3kh|g3m|g3mh|g4mh}`

Parameters

`g3k`	Generates code for the RH850 G3K core
`g3kh`	Generates code for the RH850 G3KH core
`g3m` (default)	Generates code for the RH850 G3M core
`g3mh`	Generates code for the RH850 G3MH core
`g4mh`	Generates code for the RH850 G4MH core

Description

Use this option to select the processor core for which the code will be generated.

The compiler supports all current RH850 cores and devices. The object code that the compiler generates might not be binary compatible with other, future cores.

To set related options, choose:

Project>Options>General Options>Target>Device

--c++

Syntax

```
--c++
```

Description

By default, the language supported by the compiler is C. If you use Standard C++, you must use this option to set the language the compiler uses to C++.

See also

Using C++, page 195.

Project>Options>C/C++ Compiler>Language 1>C++

and

Project>Options>C/C++ Compiler>Language 1>C++ dialect>C++

-D

Syntax

`-D` *`symbol`*`[=`*`value`*`]`

Parameters

`symbol`	The name of the preprocessor symbol
`value`	The value of the preprocessor symbol

Description

Use this option to define a preprocessor symbol. If no value is specified, `1` is used. This option can be used one or more times on the command line.

The option `-D` has the same effect as a `#define` statement at the top of the source file:

`-D`*`symbol`*

is equivalent to:

`#define` *`symbol`* `1`

To get the equivalence of:

```
#define FOO
```

specify the = sign but nothing after, for example:

```
-DFOO=
```

Project>Options>C/C++ Compiler>Preprocessor>Defined symbols

--data_model

Syntax

```
--data_model={tiny|small|medium|large}
```

Parameters

`tiny`	Specifies the Tiny data model
`small` (default)	Specifies the Small data model
`medium`	Specifies the Medium data model
`large`	Specifies the Large data model

Description

Use this option to select the data model, which means a default placement of data objects. If you do not select a data model, the compiler uses the default data model. Note that all modules of your application must use the same data model.

See also

Data models, page 73.

Project>Options>General Options>Target>Data model

--debug, -r

Syntax

```
--debug
-r
```

Description

Use the `--debug` or `-r` option to make the compiler include information in the object modules required by the IAR C-SPY® Debugger and other symbolic debuggers.

Note: Including debug information will make the object files larger than otherwise.

Project>Options>C/C++ Compiler>Output>Generate debug information

--dependencies

Syntax `--dependencies[=[i|m|n][s]] {filename|directory|+}`

Parameters

`i` (default)	Lists only the names of files
`m`	Lists in makefile style (multiple rules)
`n`	Lists in makefile style (one rule)
`s`	Suppresses system files
`+`	Gives the same output as `-o`, but with the filename extension `d`

See also *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to make the compiler list the names of all source and header files opened for input into a file with the default filename extension `i`.

Example

If `--dependencies` or `--dependencies=i` is used, the name of each opened input file, including the full path, if available, is output on a separate line. For example:

```
c:\iar\product\include\stdio.h
d:\myproject\include\foo.h
```

If `--dependencies=m` is used, the output is in makefile style. For each input file, one line containing a makefile dependency rule is produced. Each line consists of the name of the object file, a colon, a space, and the name of an input file. For example:

```
foo.o: c:\iar\product\include\stdio.h
foo.o: d:\myproject\include\foo.h
```

An example of using `--dependencies` with a popular make utility, such as gmake (GNU make):

1 Set up the rule for compiling files to be something like:

```
%.o : %.c
      $(ICC) $(ICCFLAGS) $< --dependencies=m $*.d
```

That is, in addition to producing an object file, the command also produces a dependency file in makefile style—in this example, using the extension `.d`.

2 Include all the dependency files in the makefile using, for example:

```
-include $(sources:.c=.d)
```

Because of the dash (`-`) it works the first time, when the `.d` files do not yet exist.

This option is not available in the IDE.

--deprecated_feature_warnings

Syntax

`--deprecated_feature_warnings=[+|-]`*`feature`*`[,[+|-]`*`feature`*`,...]`

Parameters

`feature`	A feature can be `attribute_syntax`, `preprocessor_extensions`, or `segment_pragmas`.

Description

Use this option to disable or enable warnings for the use of a deprecated feature. The deprecated features are:

- `attribute_syntax`

  See *--uniform_attribute_syntax*, page 290, *--no_uniform_attribute_syntax*, page 281, and *Syntax for type attributes used on data objects*, page 71.
- `preprocessor_extensions`
- `segment_pragmas`

  See the pragma directives `dataseg`, `constseg`, and `memory`. Use the `#pragma location` and `#pragma default_variable_attributes` directives instead.

Because the deprecated features will be removed in a future version of the IAR C/C++ compiler, it is prudent to remove the use of them in your source code. To do this, enable warnings for a deprecated feature. For each warning, rewrite your code so that the deprecated feature is no longer used.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--diag_error

Syntax

`--diag_error=`*`tag`*`[,`*`tag`*`,...]`

Parameters

`tag`	The number of a diagnostic message, for example, the message number `Pe117`

Description

Use this option to reclassify certain diagnostic messages as errors. An error indicates a violation of the C or C++ language rules, of such severity that object code will not be generated. The exit code will be non-zero. This option may be used more than once on the command line.

Project>Options>C/C++ Compiler>Diagnostics>Treat these as errors

--diag_remark

Syntax

`--diag_remark=tag[,tag,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Pe177`

Description

Use this option to reclassify certain diagnostic messages as remarks. A remark is the least severe type of diagnostic message and indicates a source code construction that may cause strange behavior in the generated code. This option may be used more than once on the command line.

Note: By default, remarks are not displayed—use the `--remarks` option to display them.

Project>Options>C/C++ Compiler>Diagnostics>Treat these as remarks

--diag_suppress

Syntax

`--diag_suppress=tag[,tag,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Pe117`

Description

Use this option to suppress certain diagnostic messages. These messages will not be displayed. This option may be used more than once on the command line.

Project>Options>C/C++ Compiler>Diagnostics>Suppress these diagnostics

--diag_warning

Syntax `--diag_warning=tag[,tag,...]`

Parameters

tag The number of a diagnostic message, for example, the message number `Pe826`

Description Use this option to reclassify certain diagnostic messages as warnings. A warning indicates an error or omission that is of concern, but which will not cause the compiler to stop before compilation is completed. This option may be used more than once on the command line.

Project>Options>C/C++ Compiler>Diagnostics>Treat these as warnings

--diagnostics_tables

Syntax `--diagnostics_tables {filename|directory}`

Parameters See *Rules for specifying a filename or directory as parameters*, page 252.

Description Use this option to list all possible diagnostic messages to a named file. This can be convenient, for example, if you have used a pragma directive to suppress or change the severity level of any diagnostic messages, but forgot to document why.

Typically, this option cannot be given together with other options.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--discard_unused_publics

Syntax `--discard_unused_publics`

Description Use this option to discard unused public functions and variables when compiling with the `--mfc` compiler option.

Note: Do not use this option only on parts of the application, as necessary symbols might be removed from the generated output. Use the object attribute `__root` to keep symbols that are used from outside the compilation unit, for example, interrupt handlers. If the symbol does not have the `__root` attribute and is defined in the library, the library definition will be used instead.

See also

--mfc, page 275 and *Multi-file compilation units*, page 228.

Project>Options>C/C++ Compiler>Discard unused publics

--dlib_config

Syntax

`--dlib_config filename.h|config`

Parameters

filename	
config	The default configuration file for the specified configuration will be used. Choose between: `none`, no configuration will be used `normal`, the normal library configuration will be used (default) `full`, the full library configuration will be used.

Description

Use this option to specify which library configuration to use, either by specifying an explicit file or by specifying a library configuration—in which case the default file for that library configuration will be used. Make sure that you specify a configuration that corresponds to the library you are using. If you do not specify this option, the default library configuration file will be used.

You can find the library object files and the library configuration files in the directory `rh850\lib`. For examples and information about prebuilt runtime libraries, see *Prebuilt runtime libraries*, page 135.

If you build your own customized runtime library, you can also create a corresponding customized library configuration file to specify to the compiler. For more information, see *Customizing and building your own runtime library*, page 132.

To set related options, choose:

Project>Options>General Options>Library Configuration

--do_explicit_zero_opt_in_named_sections

Syntax

`--do_explicit_zero_opt_in_named_sections`

Description

By default, the compiler treats static initialization of variables explicitly and implicitly initialized to zero the same, except for variables which are to be placed in user-named sections. For these variables, an explicit zero initialization is treated as a copy initialization, that is the same way as variables statically initialized to something other than zero.

Use this option to disable the exception for variables in user-named sections, and thus treat explicit initializations to zero as zero initializations, not copy initializations.

Example

```
int var1;                 // Implicit zero init -> zero inited
int var2 = 0;             // Explicit zero init -> zero inited
int var3 = 7;             // Not zero init      -> copy inited
int var4 @ "MYDATA";      // Implicit zero init -> zero inited
int var5 @ "MYDATA" = 0;  // Explicit zero init -> copy inited
                          // If option specified, then zero inited
int var6 @ "MYDATA" = 7;  // Not zero init      -> copy inited
```

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--double

Syntax

```
--double={32|64}
```

Parameters

`32`	32-bit doubles are used
`64` (default)	64-bit doubles are used

Description

Use this option to select the precision used by the compiler for representing the floating-point types `double` and `long double`. The compiler can use either 32-bit or 64-bit precision.

See also

Basic data types—floating-point types, page 332.

Project>Options>General Options>Target>Size of type 'double'

-e

Syntax

```
-e
```

Description

In the command line version of the compiler, language extensions are disabled by default. If you use language extensions such as extended keywords and anonymous structs and unions in your source code, you must use this option to enable them.

Note: The `-e` option and the `--strict` option cannot be used at the same time.

See also

Enabling language extensions, page 189.

Project>Options>C/C++ Compiler>Language 1>Standard with IAR extensions

Note: By default, this option is selected in the IDE.

--enable_8_byte_aligment

Syntax

`--enable_8_byte_aligment`

Description

Use this option to enable 8-byte alignment for the data types `long long` and `double`.

Project>Options>C/C++ Compiler>Optimizations>Enable 8-byte alignment

--enable_restrict

Syntax

`--enable_restrict`

Description

Enables the Standard C keyword `restrict` in C89 and C++. By default, `restrict` is recognized in Standard C and `__restrict` is always recognized.

This option can be useful for improving analysis precision during optimization.

To set this option, use **Project>Options>C/C++ Compiler>Extra options**

--enable_saddr_support

Syntax

`--enable_saddr_support`

Description

Use this option to lock the `EP` register. This enables support for short addressing in the compiler. With short addressing you can store variables in a small memory area and access them using efficient special instructions.

See also

saddr (short addressing), page 69.

Project>Options>General Options>Target>Use short address mode

--enum_is_int

Syntax
`--enum_is_int`

Description
Use this option to force the size of all enumeration types to be at least 4 bytes.

Note: This option will not consider the fact that an `enum` type can be larger than an integer type.

See also
The enum type, page 329.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--error_limit

Syntax
`--error_limit=`*`n`*

Parameters

`n`	The number of errors before the compiler stops the compilation. *`n`* must be a positive integer. `0` indicates no limit.

Description
Use the `--error_limit` option to specify the number of errors allowed before the compiler stops the compilation. By default, 100 errors are allowed.

This option is not available in the IDE.

-f

Syntax
`-f` *`filename`*

Parameters
See *Rules for specifying a filename or directory as parameters*, page 252.

Description
Use this option to make the compiler read command line options from the named file, with the default filename extension `xcl`.

In the command file, you format the items exactly as if they were on the command line itself, except that you may use multiple lines, because the newline character acts just as a space or tab character.

Both C and C++ style comments are allowed in the file. Double quotes behave in the same way as in the Microsoft Windows command line environment.

See also *--f*, page 270.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--f

Syntax

```
--f filename
```

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to make the compiler read command line options from the named file, with the default filename extension `xcl`.

In the command file, you format the items exactly as if they were on the command line itself, except that you may use multiple lines, because the newline character acts just as a space or tab character.

Both C and C++ style comments are allowed in the file. Double quotes behave in the same way as in the Microsoft Windows command line environment.

If you use the compiler option `--dependencies`, extended command line files specified using `--f` will generate a dependency, but those specified using `-f` will not generate a dependency.

See also

--dependencies, page 262 and *-f*, page 269.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--fpu

Syntax

```
--fpu={none|single|double}
```

Parameters

`none`	Makes the compiler call library routines when performing floating-point arithmetic, instead of using the floating-point unit.
`single`	Uses the floating-point unit for 32-bit operations.
`double`	Uses the floating-point unit for all operations.

Description

Use this option to configure how the compiler handles floating-point operations.

Project>Options>General Options>Target>Floating point unit

--generate_interrupt_instrumentation_code

Syntax `--generate_interrupt_instrumentation_code`

Description Use this option to generate the instrumentation code needed for the C-SPY debugger to log interrupts.

See also The *C-SPY® Debugging Guide for RH850* for information about interrupt logging.

Project>Options>C/C++ Compiler>Output>Generate interrupt instrumentation code

--guard_calls

Syntax `--guard_calls`

Description Use this option to enable guards for function static variable initialization. This option should be used in a threaded C++ environment.

See also *Managing a multithreaded environment*, page 158.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--header_context

Syntax `--header_context`

Description Occasionally, to find the cause of a problem it is necessary to know which header file that was included from which source line. Use this option to list, for each diagnostic message, not only the source position of the problem, but also the entire include stack at that point.

This option is not available in the IDE.

-I

Syntax `-I path`

Parameters

path	The search path for `#include` files

Description Use this option to specify the search paths for `#include` files. This option can be used more than once on the command line.

See also *Include file search procedure*, page 243.

Project>Options>C/C++ Compiler>Preprocessor>Additional include directories

-l

Syntax `-l[a|A|b|B|c|C|D][N][H] {filename|directory}`

Parameters

`a` (default)	Assembler list file
`A`	Assembler list file with C or C++ source as comments
`b`	Basic assembler list file. This file has the same contents as a list file produced with `-la`, except that no extra compiler-generated information (runtime model attributes, call frame information, frame size information) is included *
`B`	Basic assembler list file. This file has the same contents as a list file produced with `-lA`, except that no extra compiler generated information (runtime model attributes, call frame information, frame size information) is included *
`c`	C or C++ list file
`C` (default)	C or C++ list file with assembler source as comments
`D`	C or C++ list file with assembler source as comments, but without instruction offsets and hexadecimal byte values
`N`	No diagnostics in file
`H`	Include source lines from header files in output. Without this option, only source lines from the primary source file are included

* This makes the list file less useful as input to the assembler, but more useful for reading by a human.

See also *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to generate an assembler or C/C++ listing to a file.

Note: This option can be used one or more times on the command line.

To set related options, choose:

Project>Options>C/C++ Compiler>List

--lock_10_regs

Syntax

`--lock_10_regs`

Description

Normally `R1` and `R6–R29` are available for the compiler to use.

Use this option to prevent the compiler from using registers `R15–R24`.

Note that the register `R2` is always free to use by an operating system, because it is not used by the compiler at all.

See also

Register locking, page 218, *--lock_global_pointer_regs*, page 273, and *--lock_regs_compatibility*, page 274.

Project>Options>C/C++ Compiler>Optimizations>Lock R15–R24

--lock_global_pointer_regs

Syntax

`--lock_global_pointer_regs={0|1|2|3|4|5}`

Parameters

`0`	No registers are reserved.
`1`	Reserves register `R20`
`2`	Reserves registers `R20-R21`
`3`	Reserves registers `R20-R22`
`4`	Reserves registers `R20-R23`
`5`	Reserves registers `R20-R24`

Description

Normally, registers `R20–R24` are available for the compiler to use whichever way it needs to.

Use this option to reserve 0–5 of these registers for use by the compiler as extra global pointer (GP) registers.

See also

Register locking, page 218, --*lock_10_regs*, page 273, and --*lock_regs_compatibility*, page 274.

Project>Options>C/C++ Compiler>Optimizations>Use extra global pointers

--lock_regs_compatibility

Syntax

`--lock_regs_compatibility`

Description

Use this option to make it possible to link the module being compiled with object files that lock fewer registers than the module.

The `--lock_regs_compatibility` option is well suited for use by a third-party library provider to keep down the number of required configurations.

See also

Compatibility issues, page 218 and --*lock_10_regs*, page 273.

Project>Options>C/C++ Compiler>Optimizations>Compatible with modules locking fewer registers

--macro_positions_in_diagnostics

Syntax

`--macro_positions_in_diagnostics`

Description

Use this option to obtain position references inside macros in diagnostic messages. This is useful for detecting incorrect source code constructs in macros.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--max_cost_constexpr_call

Syntax

`--max_cost_constexpr_call=`*`limit`*

Parameters

`limit`	The number of calls and loop iterations. The default is 2000000.

Description

Use this option to specify an upper limit for the *cost* for folding a top-level `constexpr` call (function or constructor). The cost is a combination of the number of calls interpreted and the number of loop iterations preformed during the interpretation of a top-level call.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--max_depth_constexpr_call

Syntax

`--max_depth_constexpr_call=`*`limit`*

Parameters

`limit`	The depth of recursion. The default is 1000.

Description

Use this option to specify the maximum depth of recursion for folding a top-level `constexpr` call (function or constructor).

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--mfc

Syntax

`--mfc`

Description

Use this option to enable *multi-file compilation*. This means that the compiler compiles one or several source files specified on the command line as one unit, which enhances interprocedural optimizations.

Note: The compiler will generate one object file per input source code file, where the first object file contains all relevant data and the other ones are empty. If you want only the first file to be produced, use the `-o` compiler option and specify a certain output file.

Example

```
iccrh850 myfile1.c myfile2.c myfile3.c --mfc
```

See also

--discard_unused_publics, page 265, *--output, -o*, page 284, and *Multi-file compilation units*, page 228.

Project>Options>C/C++ Compiler>Multi-file compilation

--no_bit_instructions

Syntax
`--no_bit_instructions`

Description
Use this option to stop the compiler from generating bit instructions.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--no_bom

Syntax
`--no_bom`

Description
Use this option to omit the Byte Order Mark (BOM) when generating a UTF-8 output file.

See also
--*text_out*, page 290, and *Text encodings*, page 246.

Project>Options>C/C++ Compiler>Encodings>Text output file encoding

--no_call_frame_info

Syntax
`--no_call_frame_info`

Description
Normally, the compiler always generates call frame information in the output, to enable the debugger to display the call stack even in code from modules with no debug information. Use this option to disable the generation of call frame information.

See also
Call frame information, page 182.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--no_clustering

Syntax
`--no_clustering`

Description
Use this option to disable static clustering optimizations.

Note: This option has no effect at optimization levels below High.

See also
Static clustering, page 232.

Project>Options>C/C++ Compiler>Optimizations>Enable transformations>Static clustering

--no_code_motion

Syntax

`--no_code_motion`

Description

Use this option to disable code motion optimizations.

Note: This option has no effect at optimization levels below Medium.

See also

Code motion, page 231.

Project>Options>C/C++ Compiler>Optimizations>Enable transformations>Code motion

--no_cross_call

Syntax

`--no_cross_call`

Description

Use this option to disable the cross-call optimization.

Note: This option has no effect at optimization levels below High, or when optimizing Balanced or for Speed, because cross-call optimization is not enabled then.

See also

Cross call, page 233.

Project>Options>C/C++ Compiler>Optimizations>Enable transformations>Cross call

--no_cse

Syntax

`--no_cse`

Description

Use this option to disable common subexpression elimination.

Note: This option has no effect at optimization levels below Medium.

See also

Common subexpression elimination, page 231.

Project>Options>C/C++ Compiler>Optimizations>Enable transformations>Common subexpression elimination

--no_data_model_rt_attribute

Syntax

```
--no_data_model_rt_attribute
```

Description

Suppresses the generation of the runtime attribute for the data model. This is useful when compiling a file that might be used together with other files built using other data models, for example when providing a third-party library.

Note that great care must be taken to ensure that nothing that is provided to other modules rely on the selected data model, in particular global variables without an explicit memory attribute.

For example, the prebuilt libraries are built using this option.

To set this option, use **Project>Options>C/C++ Compiler>Extra options**

--no_fragments

Syntax

```
--no_fragments
```

Description

Use this option to disable section fragment handling. Normally, the toolset uses IAR proprietary information for transferring section fragment information to the linker. The linker uses this information to remove unused code and data, and further minimize the size of the executable image. When you use this option, this information is not output in the object files.

See also

Keeping symbols and sections, page 111.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**

--no_inline

Syntax

```
--no_inline
```

Description

Use this option to disable function inlining.

See also

Inlining functions, page 85.

Project>Options>C/C++ Compiler>Optimizations>Enable transformations>Function inlining

--no_loop

Syntax `--no_loop`

Description Use this option to disable the use of the `LOOP` instruction in your code.

Note: This option has no effect at optimization levels below High.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--no_path_in_file_macros

Syntax `--no_path_in_file_macros`

Description Use this option to exclude the path from the return value of the predefined preprocessor symbols `__FILE__` and `__BASE_FILE__`.

See also *Description of predefined preprocessor symbols*, page 404.

This option is not available in the IDE.

--no_scheduling

Syntax `--no_scheduling`

Description Use this option to disable the instruction scheduler.

Note: This option has no effect at optimization levels below High.

See also *Instruction scheduling*, page 233.

Project>Options>C/C++ Compiler>Optimizations>Enable transformations>Instruction scheduling

--no_size_constraints

Syntax `--no_size_constraints`

Description Use this option to relax the normal restrictions for code size expansion when optimizing for high speed.

Note: This option has no effect unless used with `-Ohs`.

See also

Speed versus size, page 230.

Project>Options>C/C++ Compiler>Optimizations>Enable transformations>No size constraints

--no_static_destruction

Syntax

`--no_static_destruction`

Description

Normally, the compiler emits code to destroy C++ static variables that require destruction at program exit. Sometimes, such destruction is not needed.

Use this option to suppress the emission of such code.

See also

Setting up the atexit limit, page 112.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--no_system_include

Syntax

`--no_system_include`

Description

By default, the compiler automatically locates the system include files. Use this option to disable the automatic search for system include files. In this case, you might need to set up the search path by using the `-I` compiler option.

See also

--dlib_config, page 266, and *--system_include_dir*, page 289.

Project>Options>C/C++ Compiler>Preprocessor>Ignore standard include directories

--no_tbaa

Syntax

`--no_tbaa`

Description

Use this option to disable type-based alias analysis.

Note: This option has no effect at optimization levels below High.

See also

Type-based alias analysis, page 232.

Project>Options>C/C++ Compiler>Optimizations>Enable transformations>Type-based alias analysis

--no_typedefs_in_diagnostics

Syntax

```
--no_typedefs_in_diagnostics
```

Description

Use this option to disable the use of typedef names in diagnostics. Normally, when a type is mentioned in a message from the compiler, most commonly in a diagnostic message of some kind, the typedef names that were used in the original declaration are used whenever they make the resulting text shorter.

Example

```
typedef int (*MyPtr)(char const *);
MyPtr p = "My text string";
```

will give an error message like this:

```
Error[Pe144]: a value of type "char *" cannot be used to
initialize an entity of type "MyPtr"
```

If the `--no_typedefs_in_diagnostics` option is used, the error message will be like this:

```
Error[Pe144]: a value of type "char *" cannot be used to
initialize an entity of type "int (*)(char const *)"
```

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--no_uniform_attribute_syntax

Syntax

```
--no_uniform_attribute_syntax
```

Description

Use this option to apply the default syntax rules to IAR type attributes specified before a type specifier.

See also

--uniform_attribute_syntax, page 290 and *Syntax for type attributes used on data objects*, page 71.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--no_unroll

Syntax

```
--no_unroll
```

Description

Use this option to disable loop unrolling.

Note: This option has no effect at optimization levels below High.

See also

Loop unrolling, page 231.

Project>Options>C/C++ Compiler>Optimizations>Enable transformations>Loop unrolling

--no_warnings

Syntax

```
--no_warnings
```

Description

By default, the compiler issues warning messages. Use this option to disable all warning messages.

This option is not available in the IDE.

--no_wrap_diagnostics

Syntax

```
--no_wrap_diagnostics
```

Description

By default, long lines in diagnostic messages are broken into several lines to make the message easier to read. Use this option to disable line wrapping of diagnostic messages.

This option is not available in the IDE.

--nonportable_path_warnings

Syntax

```
--nonportable_path_warnings
```

Description

Use this option to make the compiler generate a warning when characters in the path used for opening a source file or header file are lower case instead of upper case, or vice versa, compared with the path in the file system.

This option is not available in the IDE.

-O

Syntax `-O[n|l|m|h|hs|hz]`

Parameters

`n`	**None* (Best debug support)**
`l` (default)	Low*
`m`	Medium
`h`	High, balanced
`hs`	High, favoring speed
`hz`	High, favoring size

*The most important difference between None and Low is that at None, all non-static variables will live during their entire scope.

Description

Use this option to set the optimization level to be used by the compiler when optimizing the code. If no optimization option is specified, the optimization level Low is used by default. If only `-O` is used without any parameter, the optimization level High balanced is used.

A low level of optimization makes it relatively easy to follow the program flow in the debugger, and, conversely, a high level of optimization makes it relatively hard.

See also

Controlling compiler optimizations, page 228.

Project>Options>C/C++ Compiler>Optimizations

--only_stdout

Syntax `--only_stdout`

Description

Use this option to make the compiler use the standard output stream (`stdout`), and messages that are normally directed to the error output stream (`stderr`).

This option is not available in the IDE.

--output, -o

Syntax
```
--output {filename|directory}
-o {filename|directory}
```

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

Description

By default, the object code output produced by the compiler is located in a file with the same name as the source file, but with the extension `o`. Use this option to explicitly specify a different output filename for the object code output.

This option is not available in the IDE.

--pending_instantiations

Syntax
```
--pending_instantiations number
```

Parameters

number	An integer that specifies the limit, where `64` is default. If `0` is used, there is no limit.

Description

Use this option to specify the maximum number of instantiations of a given C++ template that is allowed to be in process of being instantiated at a given time. This is used for detecting recursive instantiations.

Project>Options>C/C++ Compiler>Extra Options

--predef_macros

Syntax
```
--predef_macros {filename|directory}
```

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to list all symbols defined by the compiler or on the command line. (Symbols defined in the source code are not listed.) When using this option, make sure to also use the same options as for the rest of your project.

If a filename is specified, the compiler stores the output in that file. If a directory is specified, the compiler stores the output in that directory, in a file with the `predef` filename extension.

Note: This option requires that you specify a source file on the command line.

This option is not available in the IDE.

--preinclude

Syntax

`--preinclude includefile`

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to make the compiler read the specified include file before it starts to read the source file. This is useful if you want to change something in the source code for the entire application, for instance if you want to define a new symbol.

Project>Options>C/C++ Compiler>Preprocessor>Preinclude file

--preprocess

Syntax

`--preprocess[=[c][n][s]] {filename|directory}`

Parameters

`c`	Include comments
`n`	Preprocess only
`s`	Suppress `#line` directives

See also *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to generate preprocessed output to a named file.

Project>Options>C/C++ Compiler>Preprocessor>Preprocessor output to file

--public_equ

Syntax

`--public_equ symbol[=value]`

Parameters

`symbol`	The name of the assembler symbol to be defined

value	An optional value of the defined assembler symbol

Description

This option is equivalent to defining a label in assembler language using the `EQU` directive and exporting it using the `PUBLIC` directive. This option can be used more than once on the command line.

This option is not available in the IDE.

--relaxed_fp

Syntax

```
--relaxed_fp
```

Description

Use this option to allow the compiler to relax the language rules and perform more aggressive optimization of floating-point expressions. This option improves performance for floating-point expressions that fulfill these conditions:

- The expression consists of both single and double-precision values
- The double-precision values can be converted to single precision without loss of accuracy
- The result of the expression is converted to single precision.

Note: Performing the calculation in single precision instead of double precision might cause a loss of accuracy.

When the `--relaxed_fp` option is used, `errno` might not be set according to Standard C for negative arguments to the function `sqrt`. Therefore, your source code should not rely on `errno`.

Example

```
float F(float a, float b)
{
  return a + b * 3.0;
}
```

The C standard states that `3.0` in this example has the type `double` and therefore the whole expression should be evaluated in `double` precision. However, when the `--relaxed_fp` option is used, 3.0 will be converted to `float` and the whole expression can be evaluated in `float` precision.

To set related options, choose:

Project>Options>C/C++ Compiler>Language 2>Floating-point semantics

--remarks

Syntax `--remarks`

Description The least severe diagnostic messages are called remarks. A remark indicates a source code construct that may cause strange behavior in the generated code. By default, the compiler does not generate remarks. Use this option to make the compiler generate remarks.

See also *Severity levels*, page 249.

Project>Options>C/C++ Compiler>Diagnostics>Enable remarks

--require_prototypes

Syntax `--require_prototypes`

Description Use this option to force the compiler to verify that all functions have proper prototypes. Using this option means that code containing any of the following will generate an error:

- A function call of a function with no declaration, or with a Kernighan & Ritchie C declaration
- A function definition of a public function with no previous prototype declaration
- An indirect function call through a function pointer with a type that does not include a prototype.

Project>Options>C/C++ Compiler>Language 1>Require prototypes

--section

Syntax `--section` *`OldName=NewName`*

Description The compiler places functions and data objects into named sections which are referred to by the IAR ILINK Linker. Use this option to change the name of the section *`OldName`* to *`NewName`*.

This is useful if you want to place your code or data in different address ranges and you find the `@` notation, alternatively the `#pragma location` directive, insufficient.

Note: Any changes to the section names require corresponding modifications in the linker configuration file.

Example

To place functions in the section `MyText`, use:

```
--section .text=MyText
```

See also

Controlling data and function placement in memory, page 224.

Project>Options>C/C++ Compiler>Output>Code section name

--silent

Syntax

```
--silent
```

Description

By default, the compiler issues introductory messages and a final statistics report. Use this option to make the compiler operate without sending these messages to the standard output stream (normally the screen).

This option does not affect the display of error and warning messages.

This option is not available in the IDE.

--source_encoding

Syntax

```
--source_encoding {locale|utf8}
```

Parameters

`locale`	The default source encoding is the system locale encoding.
`utf8`	The default source encoding is the UTF-8 encoding.

Description

When reading a source file with no Byte Order Mark (BOM), use this option to specify the encoding. If this option is not specified and the source file does not have a BOM, the Raw encoding will be used.

See also

Text encodings, page 246.

Project>Options>C/C++ Compiler>Encodings>Default source file encoding

--stack_protection

Syntax `--stack_protection`

Description Use this option to enable stack protection for the functions that are considered to need it.

See also *Stack protection*, page 87.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--strict

Syntax `--strict`

Description By default, the compiler accepts a relaxed superset of Standard C and C++. Use this option to ensure that the source code of your application instead conforms to strict Standard C and C++.

Note: The `-e` option and the `--strict` option cannot be used at the same time.

See also *Enabling language extensions*, page 189.

Project>Options>C/C++ Compiler>Language 1>Language conformance>Strict

--system_include_dir

Syntax `--system_include_dir` *`path`*

Parameters

`path`

Description By default, the compiler automatically locates the system include files. Use this option to explicitly specify a different path to the system include files. This might be useful if you have not installed IAR Embedded Workbench in the default location.

See also --*dlib_config*, page 266, and --*no_system_include*, page 280.

This option is not available in the IDE.

--text_out

Syntax `--text_out {utf8|utf16le|utf16be|locale}`

Parameters

`utf8`	Uses the UTF-8 encoding
`utf16le`	Uses the UTF-16 little-endian encoding
`utf16be`	Uses the UTF-16 big-endian encoding
`locale`	Uses the system locale encoding

Description

Use this option to specify the encoding to be used when generating a text output file.

The default for the compiler list files is to use the same encoding as the main source file. The default for all other text files is UTF-8 with a Byte Order Mark (BOM).

If you want text output in UTF-8 encoding without a BOM, use the option `--no_bom`.

See also

--no_bom, page 276 and *Text encodings*, page 246.

Project>Options>C/C++ Compiler>Encodings>Text output file encoding

--uniform_attribute_syntax

Syntax `--uniform_attribute_syntax`

Description

By default, an IAR type attribute specified before the type specifier applies to the object or typedef itself, and not to the type specifier, as `const` and `volatile` do. If you specify this option, IAR type attributes obey the same syntax rules as `const` and `volatile`.

The default for IAR type attributes is to *not* use uniform attribute syntax.

See also

--no_uniform_attribute_syntax, page 281 and *Syntax for type attributes used on data objects*, page 71.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--use_c++_inline

Syntax `--use_c++_inline`

Description Standard C uses slightly different semantics for the `inline` keyword than C++ does. Use this option if you want C++ semantics when you are using C.

See also *Inlining functions*, page 85.

Project>Options>C/C++ Compiler>Language 1>C dialect>C++ inline semantics

--use_paths_as_written

Syntax `--use_paths_as_written`

Description By default, the compiler ensures that all paths in the debug information are absolute, even if not originally specified that way.

If you use this option, paths that were originally specified as relative will be relative in the debug information.

The paths affected by this option are:

- the paths to source files
- the paths to header files that are found using an include path that was specified as relative

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--use_unix_directory_separators

Syntax `--use_unix_directory_separators`

Description Use this option to make DWARF debug information use `/` (instead of `\`) as directory separators in file paths.

This option can be useful if you have a debugger that requires directory separators in UNIX style.

To set this option, use **Project>Options>C/C++ Compiler>Extra Options**.

--utf8_text_in

Syntax
`--utf8_text_in`

Description
Use this option to specify that the compiler shall use UTF-8 encoding when reading a text input file with no Byte Order Mark (BOM).

Note: This option does not apply to source files.

See also
Text encodings, page 246.

Project>Options>C/C++ Compiler>Encodings>Default input file encoding

--version

Syntax
`--version`

Description
Use this option to make the compiler send version information to the console and then exit.

This option is not available in the IDE.

--vla

Syntax
`--vla`

Description
Use this option to enable support for variable length arrays in C code. Such arrays are located on the heap. This option requires Standard C and cannot be used together with the `--c89` compiler option.

Note: `--vla` should not be used together with the `longjmp` library function, as that can lead to memory leakages.

See also
C language overview, page 187.

Project>Options>C/C++ Compiler>Language 1>C dialect>Allow VLA

--warn_about_c_style_casts

Syntax

`--warn_about_c_style_casts`

Description

Use this option to make the compiler warn when C-style casts are used in C++ source code.

This option is not available in the IDE.

--warnings_affect_exit_code

Syntax

`--warnings_affect_exit_code`

Description

By default, the exit code is not affected by warnings, because only errors produce a non-zero exit code. With this option, warnings will also generate a non-zero exit code.

This option is not available in the IDE.

--warnings_are_errors

Syntax

`--warnings_are_errors`

Description

Use this option to make the compiler treat all warnings as errors. If the compiler encounters an error, no object code is generated. Warnings that have been changed into remarks are not treated as errors.

Note: Any diagnostic messages that have been reclassified as warnings by the option `--diag_warning` or the `#pragma diag_warning` directive will also be treated as errors when `--warnings_are_errors` is used.

See also

--*diag_warning*, page 265.

Project>Options>C/C++ Compiler>Diagnostics>Treat all warnings as errors

Linker options

- Summary of linker options
- Descriptions of linker options

For general syntax rules, see *Options syntax*, page 251.

Summary of linker options

This table summarizes the linker options:

Command line option	Description
`--accurate_math`	Uses more accurate math functions
`--advanced_heap`	Uses an advanced heap
`--basic_heap`	Uses a basic heap
`--call_graph`	Produces a call graph file in XML format
`--config`	Specifies the linker configuration file to be used by the linker
`--config_def`	Defines symbols for the configuration file
`--config_search`	Specifies more directories to search for linker configuration files
`--cpp_init_routine`	Specifies a user-defined C++ dynamic initialization routine
`--debug_lib`	Uses the C-SPY debug library
`--default_to_complex_ranges`	Makes `complex ranges` the default decompressor in `initialize` directives
`--define_symbol`	Defines symbols that can be used by the application
`--dependencies`	Lists file dependencies
`--diag_error`	Treats these message tags as errors
`--diag_remark`	Treats these message tags as remarks
`--diag_suppress`	Suppresses these diagnostic messages
`--diag_warning`	Treats these message tags as warnings
`--diagnostics_tables`	Lists all diagnostic messages

Table 26: Linker options summary

Command line option	Description
`--enable_stack_usage`	Enables stack usage analysis
`--entry`	Treats the symbol as a root symbol and as the start of the application
`--entry_list_in_address_order`	Generates an additional entry list in the map file sorted in address order
`--error_limit`	Specifies the allowed number of errors before linking stops
`--export_builtin_config`	Produces an `icf` file for the default configuration
`-f`	Extends the command line
`--f`	Extends the command line, optionally with a dependency.
`--force_output`	Produces an output file even if errors occurred
`--image_input`	Puts an image file in a section
`--inline`	Inlines small routines
`--keep`	Forces a symbol to be included in the application
`-L`	Specifies more directories to search for object and library files. Alias for `--search`.
`--log`	Enables log output for selected topics
`--log_file`	Directs the log to a file
`--mangled_names_in_messages`	Adds mangled names in messages
`--manual_dynamic_initialization`	Suppresses automatic initialization during system startup
`--map`	Produces a map file
`--merge_duplicate_sections`	Merges equivalent read-only sections
`--misrac1998`	Enables error messages specific to MISRA-C:1998. See the *IAR Embedded Workbench® MISRA C:1998 Reference Guide*.
`--misrac2004`	Enables error messages specific to MISRA-C:2004. See the *IAR Embedded Workbench® MISRA C:2004 Reference Guide*.
`--misrac_verbose`	Enables verbose logging of MISRA C checking. See the *IAR Embedded Workbench® MISRA C:1998 Reference Guide* and the *IAR Embedded Workbench® MISRA C:2004 Reference Guide*.

Table 26: Linker options summary (Continued)

Command line option	Description
`--no_bom`	Omits the Byte Order Mark from UTF-8 output files
`--no_entry`	Sets the entry point to zero
`--no_fragments`	Disables section fragment handling
`--no_free_heap`	Uses the smallest possible heap implementation
`--no_inline`	Excludes functions from small function inlining
`--no_library_search`	Disables automatic runtime library search
`--no_locals`	Removes local symbols from the ELF executable image.
`--no_range_reservations`	Disables range reservations for absolute symbols
`--no_remove`	Disables removal of unused sections
`--no_vfe`	Disables Virtual Function Elimination
`--no_warnings`	Disables generation of warnings
`--no_wrap_diagnostics`	Does not wrap long lines in diagnostic messages
`-o`	Sets the object filename. Alias for `--output`.
`--only_stdout`	Uses standard output only
`--output`	Sets the object filename
`--place_holder`	Reserve a place in ROM to be filled by some other tool, for example, a checksum calculated by `ielftool`.
`--preconfig`	Reads the specified file before reading the linker configuration file
`--printf_multibytes`	Makes the `printf` formatter support multibytes
`--redirect`	Redirects a reference to a symbol to another symbol
`--remarks`	Enables remarks
`--scanf_multibytes`	Makes the `scanf` formatter support multibytes
`--search`	Specifies more directories to search for object and library files
`--silent`	Sets silent operation
`--small_math`	Uses smaller math functions
`--stack_usage_control`	Specifies a stack usage control file
`--strip`	Removes debug information from the executable image

Table 26: Linker options summary (Continued)

Command line option	Description
`--text_out`	Specifies the encoding for text output files
`--threaded_lib`	Configures the runtime library for use with threads
`--timezone_lib`	Enables the time zone and daylight savings time functionality in the library
`--use_full_std_template_names`	Enables full names for standard C++ templates
`--utf8_text_in`	Uses the UTF-8 encoding for text input files
`--version`	Sends version information to the console and then exits
`--vfe`	Controls Virtual Function Elimination
`--warnings_affect_exit_code`	Warnings affects exit code
`--warnings_are_errors`	Warnings are treated as errors
`--whole_archive`	Treats every object file in the archive as if it was specified on the command line.

Table 26: Linker options summary (Continued)

Descriptions of linker options

The following section gives detailed reference information about each linker option.

To comply with the Renesas ABI, the compiler generates assembler labels for symbol and function names by prefixing an underscore. You must remember to add this extra underscore when you refer to C symbols in any of the linker options, such as `--define_symbol` and `--redirect`, or in directives in the linker configuration file, such as `define symbol`. For example, `main` must be written as `_main`.

If you use the options page **Extra Options** to specify specific command line options, the IDE does not perform an instant check for consistency problems like conflicting options, duplication of options, or use of irrelevant options.

--accurate_math

Syntax

`--accurate_math`

Description

Use this option to use math library versions designed to provide better accuracy (but which are larger) than the default versions.

See also

Math functions, page 141.

Project>Options>General Options>Library Options 1>Math functions

--advanced_heap

Syntax `--advanced_heap`

Description Use this option to use an advanced heap.

See also *Advanced, basic, and no-free heap*, page 204.

Project>Options>General Options>Library options 2>Heap selection

--basic_heap

Syntax `--basic_heap`

Description Use this option to use the basic heap handler.

See also *Advanced, basic, and no-free heap*, page 204.

Project>Options>General Options>Library options 2>Heap selection

--call_graph

Syntax `--call_graph {`*`filename`*`|`*`directory`*`}`

Parameters See *Rules for specifying a filename or directory as parameters*, page 252.

Description Use this option to produce a call graph file. If no filename extension is specified, the extension `cgx` is used. This option can only be used once on the command line.

Using this option enables stack usage analysis in the linker.

See also *Stack usage analysis*, page 99

Project>Options>Linker>Advanced>Call graph output (XML)

--config

Syntax `--config` *`filename`*

Parameters See *Rules for specifying a filename or directory as parameters*, page 252.

Description Use this option to specify the configuration file to be used by the linker (the default filename extension is `icf`). If no configuration file is specified, a default configuration is used. This option can only be used once on the command line.

See also The chapter *The linker configuration file*.

Project>Options>Linker>Config>Linker configuration file

--config_def

Syntax `--config_def` *`symbol=constant_value`*

Parameters

`symbol`	The name of the symbol to be used in the configuration file.
`constant_value`	The constant value of the configuration symbol.

Description Use this option to define a constant configuration symbol to be used in the configuration file. This option has the same effect as the `define symbol` directive in the linker configuration file. This option can be used more than once on the command line.

See also *--define_symbol*, page 302 and *Interaction between ILINK and the application*, page 116.

Project>Options>Linker>Config>Defined symbols for configuration file

--config_search

Syntax `--config_search` *`path`*

Parameters

`path`	A path to a directory where the linker should search for linker configuration include files.

Description

Use this option to specify more directories to search for files when processing an `include` directive in a linker configuration file.

By default, the linker searches for configuration include files only in the system configuration directory. To specify more than one search directory, use this option for each path.

See also

include directive, page 456.

To set this option, use **Project>Options>Linker>Extra Options**.

--cpp_init_routine

Syntax

`--cpp_init_routine` *`routine`*

Parameters

`routine`	A user-defined C++ dynamic initialization routine.

Description

When using the IAR C/C++ compiler and the standard library, C++ dynamic initialization is handled automatically. In other cases you might need to use this option.

If any sections with the section type `INIT_ARRAY` or `PREINIT_ARRAY` are included in your application, the C++ dynamic initialization routine is considered to be needed. By default, this routine is named `__iar_cstart_call_ctors` and is called by the startup code in the standard library. Use this option if you require another routine to handle the initialization, for instance if you are not using the standard library.

To set this option, use **Project>Options>Linker>Extra Options**.

--debug_lib

Syntax

`--debug_lib`

Description

Use this option to enable C-SPY emulated I/O.

Note: If your code contains calls to I/O functions, performance analysis will not work correctly if this option is selected. See the *C-SPY® Debugging Guide for RH850* for more information.

See also

Briefly about C-SPY emulated I/O, page 126.

Project>Options>Linker>Library>Include C-SPY debugging support

--default_to_complex_ranges

Syntax `--default_to_complex_ranges`

Description

Normally, if `initialize` directives in a linker configuration file do not specify `simple ranges` or `complex ranges`, the linker uses `simple ranges` if the associated `section placement` directives use single range regions.

Use this option to make the linker always use `complex ranges` by default. This was the behavior of the linker before the introduction of `simple ranges` and `complex ranges`.

See also

initialize directive, page 440.

Project>Options>Linker>Extra Options

--define_symbol

Syntax `--define_symbol` *`symbol=constant_value`*

Parameters

`symbol`	The name of the constant symbol that can be used by the application.
`constant_value`	The constant value of the symbol.

Description

Use this option to define a constant symbol, that is a label, that can be used by your application. This option can be used more than once on the command line.

Note: This option is different from the `define symbol` directive.

See also

--config_def, page 300 and *Interaction between ILINK and the application*, page 116.

Project>Options>Linker>#define>Defined symbols

--dependencies

Syntax

```
--dependencies[=[i|m]] {filename|directory}
```

Parameters

`i` (default)	Lists only the names of files
`m`	Lists in makefile style

See also *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to make the linker list the names of the linker configuration, object, and library files opened for input into a file with the default filename extension `i`.

Example

If `--dependencies` or `--dependencies=i` is used, the name of each opened input file, including the full path, if available, is output on a separate line. For example:

```
c:\myproject\foo.o
d:\myproject\bar.o
```

If `--dependencies=m` is used, the output is in makefile style. For each input file, one line containing a makefile dependency rule is produced. Each line consists of the name of the output file, a colon, a space, and the name of an input file. For example:

```
a.out: c:\myproject\foo.o
a.out: d:\myproject\bar.o
```

This option is not available in the IDE.

--diag_error

Syntax

```
--diag_error=tag[,tag,...]
```

Parameters

`tag`	The number of a diagnostic message, for example, the message number `Pe117`

Description

Use this option to reclassify certain diagnostic messages as errors. An error indicates a problem of such severity that an executable image will not be generated. The exit code will be non-zero. This option may be used more than once on the command line.

Project>Options>Linker>Diagnostics>Treat these as errors

--diag_remark

Syntax `--diag_remark=tag[,tag,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Go109`

Description

Use this option to reclassify certain diagnostic messages as remarks. A remark is the least severe type of diagnostic message and indicates a construction that may cause strange behavior in the executable image.

Note: Not all diagnostic messages can be reclassified. This option may be used more than once on the command line.

Note: By default, remarks are not displayed—use the `--remarks` option to display them.

Project>Options>Linker>Diagnostics>Treat these as remarks

--diag_suppress

Syntax `--diag_suppress=tag[,tag,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Pa180`

Description

Use this option to suppress certain diagnostic messages. These messages will not be displayed. This option may be used more than once on the command line.

Note: Not all diagnostic messages can be reclassified.

Project>Options>Linker>Diagnostics>Suppress these diagnostics

--diag_warning

Syntax

`--diag_warning=tag[,tag,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Li004`

Description

Use this option to reclassify certain diagnostic messages as warnings. A warning indicates an error or omission that is of concern, but which will not cause the linker to stop before linking is completed. This option may be used more than once on the command line.

Note: Not all diagnostic messages can be reclassified.

Project>Options>Linker>Diagnostics>Treat these as warnings

--diagnostics_tables

Syntax

`--diagnostics_tables {filename|directory}`

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to list all possible diagnostic messages in a named file. This can be convenient, for example, if you have used a pragma directive to suppress or change the severity level of any diagnostic messages, but forgot to document why.

This option cannot be given together with other options.

This option is not available in the IDE.

--enable_stack_usage

Syntax

`--enable_stack_usage`

Description

Use this option to enable stack usage analysis. If a linker map file is produced, a stack usage chapter is included in the map file.

Note: If you use at least one of the `--stack_usage_control` or `--call_graph` options, stack usage analysis is automatically enabled.

See also

Stack usage analysis, page 99.

Project>Options>Linker>Advanced>Enable stack usage analysis

--entry

Syntax `--entry symbol`

Parameters

symbol	The name of the symbol to be treated as a root symbol and start label

Description

Use this option to make a symbol be treated as a root symbol and the start label of the application. This is useful for loaders. If this option is not used, the default start symbol is used (see *Building applications—an overview*, page 63). A root symbol is kept whether or not it is referenced from the rest of the application, provided its module is included. A module in an object file is always included but a module part of a library is only included if needed.

Note: The label referred to must be available in your application. You must also make sure that the reset vector refers to the new start label, for example `--redirect __iar_program_start2=_myStartLabel`.

See also

--no_entry, page 314.

Project>Options>Linker>Library>Override default program entry

--entry_list_in_address_order

Syntax `--entry_list_in_address_order`

Description

Use this option to generate an additional entry list in the map file. This entry list will be sorted in address order.

To set this option use **Project>Options>Linker>Extra Options**.

--error_limit

Syntax `--error_limit=n`

Parameters

n The number of errors before the linker stops linking. *n* must be a positive integer. `0` indicates no limit.

Description Use the `--error_limit` option to specify the number of errors allowed before the linker stops the linking. By default, 100 errors are allowed.

This option is not available in the IDE.

--export_builtin_config

Syntax `--export_builtin_config filename`

Parameters See *Rules for specifying a filename or directory as parameters*, page 252.

Description Exports the configuration used by default to a file.

This option is not available in the IDE.

-f

Syntax `-f filename`

Parameters See *Rules for specifying a filename or directory as parameters*, page 252.

Description Use this option to make the linker read command line options from the named file, with the default filename extension `xcl`.

In the command file, you format the items exactly as if they were on the command line itself, except that you may use multiple lines, because the newline character acts just as a space or tab character.

Both C and C++ style comments are allowed in the file. Double quotes behave in the same way as in the Microsoft Windows command line environment.

See also *--f*, page 308.

To set this option, use **Project>Options>Linker>Extra Options**.

--f

Syntax `--f` *`filename`*

Parameters See *Rules for specifying a filename or directory as parameters*, page 252.

Description Use this option to make the linker read command line options from the named file, with the default filename extension `xcl`.

In the command file, you format the items exactly as if they were on the command line itself, except that you may use multiple lines, because the newline character acts just as a space or tab character.

Both C and C++ style comments are allowed in the file. Double quotes behave in the same way as in the Microsoft Windows command line environment.

If you use the linker option `--dependencies`, extended command line files specified using `--f` will generate a dependency, but those specified using `-f` will not generate a dependency.

See also *--dependencies*, page 262 and *-f*, page 269.

To set this option, use **Project>Options>Linker>Extra Options**.

--force_output

Syntax `--force_output`

Description Use this option to produce an output executable image regardless of any linking errors.

To set this option, use **Project>Options>Linker>Extra Options**

--image_input

Syntax

`--image_input` *`filename`* `[,`*`symbol`*`,[`*`section`*`[,`*`alignment`*`]]]`

Parameters

`filename`	The pure binary file containing the raw image you want to link
`symbol`	The symbol which the binary data can be referenced with.
`section`	The section where the binary data will be placed. Default is `.text`.
`alignment`	The alignment of the section. Default is `1`.

Description

Use this option to link pure binary files in addition to the ordinary input files. The file's entire contents are placed in the section, which means it can only contain pure binary data.

Note: Just as for sections from object files, sections created by using the `--image_input` option are not included unless actually needed. You can either specify a symbol in the option and reference this symbol in your application (or use a `--keep` option), or you can specify a section name and use the `keep` directive in a linker configuration file to ensure that the section is included.

Example

```
--image_input bootstrap.abs,Bootstrap,CSTARTUPCODE,4
```

The contents of the pure binary file `bootstrap.abs` are placed in the section `CSTARTUPCODE`. The section where the contents are placed is 4-byte aligned and will only be included if your application (or the command line option `--keep`) includes a reference to the symbol `Bootstrap`.

See also

--*keep*, page 310.

Project>Options>Linker>Input>Raw binary image

--inline

Syntax

`--inline`

Description

Some routines are so small that they can fit in the space of the instruction that calls the routine. Use this option to make the linker replace the call of a routine with the body of the routine, where applicable.

See also

Small function inlining, page 121.

Project>Options>Linker>Optimizations>Inline small routines

--keep

Syntax

`--keep symbol`

Parameters

symbol	The name of the symbol to be treated as a root symbol

Description

Normally, the linker keeps a symbol only if it is needed by your application. Use this option to make a symbol always be included in the final application.

Project>Options>Linker>Input>Keep symbols

--log

Syntax `--log topic[,topic,...]`

Parameters *topic* can be one of:

`call_graph`	Lists the call graph as seen by stack usage analysis.
`crt_routine_selection`	Lists details of the selection process for runtime routines—what definitions were available, what the requirements were, and which decision the process resulted in.
`fragment_info`	Lists all fragments by number. The information contains the section they correspond to (name, section number and file) and the fragment size.
`initialization`	Lists copy batches and the compression selected for each batch.
`inlining`	Lists the functions that were inlined, and which sections (name, section number and file) they were inlined in. Note that inlining in the linker must be enabled by the `--inline` linker option. See *--inline*, page 309
`libraries`	Lists all decisions made by the automatic library selector. This might include extra symbols needed (`--keep`), redirections (`--redirect`), as well as which runtime libraries that were selected.
`merging`	Lists the sections (name, section number and file) that were merged and which symbol redirections this resulted in. Note that section merging must be enabled by the `--merge_duplicate_sections` linker option. See *--merge_duplicate_sections*, page 314.
`modules`	Lists each module that is selected for inclusion in the application, and which symbol that caused it to be included.
`redirects`	Lists redirected symbols.
`sections`	Lists each symbol and section fragment that is selected for inclusion in the application, and the dependence that caused it to be included.
`unused_fragments`	Lists those section fragments that were not included in the application.

Description Use this option to make the linker log information to `stdout`. The log information can be useful for understanding why an executable image became the way it is.

See also

--*log_file*, page 312.

Project>Options>Linker>List>Generate log

--log_file

Syntax

`--log_file filename`

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to direct the log output to the specified file.

See also

--*log*, page 311.

Project>Options>Linker>List>Generate log

--mangled_names_in_messages

Syntax

`--mangled_names_in_messages`

Description

Use this option to produce both mangled and demangled names for C/C++ symbols in messages. Mangling is a technique used for mapping a complex C name or a C++ name—for example, for overloading—into a simple name. For example, `void h(int, char)` becomes `_Z1hic`.

This option is not available in the IDE.

--manual_dynamic_initialization

Syntax

`--manual_dynamic_initialization`

Description

Normally, dynamic initialization (typically initialization of C++ objects with static storage duration) is performed automatically during application startup. If you use `--manual_dynamic_initialization`, you must call `__iar_dynamic_initialization` at some later point for this initialization to be done.

The function `__iar_dynamic_initialization` is declared in the header file `iar_dynamic_init.h`.

To set this option use **Project>Options>Linker>Extra Options**.

--map

Syntax `--map {filename|directory}`

Description Use this option to produce a linker memory map file. The map file has the default filename extension `map`. The map file contains:

- Linking summary in the map file header which lists the version of the linker, the current date and time, and the command line that was used.
- Runtime attribute summary which lists runtime attributes.
- Placement summary which lists each section/block in address order, sorted by placement directives.
- Initialization table layout which lists the data ranges, packing methods, and compression ratios.
- Module summary which lists contributions from each module to the image, sorted by directory and library.
- Entry list which lists all public and some local symbols in alphabetical order, indicating which module they came from.
- Some of the bytes might be reported as *shared*.

  Shared objects are functions or data objects that are shared between modules. If any of these occur in more than one module, only one copy is retained. For example, in some cases inline functions are not inlined, which means that they are marked as shared, because only one instance of each function will be included in the final application. This mechanism is also sometimes used for compiler-generated code or data not directly associated with a particular function or variable, and when only one instance is required in the final application.

This option can only be used once on the command line.

Project>Options>Linker>List>Generate linker map file

--merge_duplicate_sections

Syntax

```
--merge_duplicate_sections
```

Description

Use this option to keep only one copy of equivalent read-only sections.

Note: This can cause different functions or constants to have the same address, so an application that depends on the addresses being different will not work correctly with this option enabled.

See also

Duplicate section merging, page 122.

Project>Options>Linker>Optimizations>Merge duplicate sections

--no_bom

Syntax

```
--no_bom
```

Description

Use this option to omit the Byte Order Mark (BOM) when generating a UTF-8 output file.

See also

--*text_out*, page 322 and *Text encodings*, page 246.

Project>Options>Linker>Encodings>Text output file encoding

--no_entry

Syntax

```
--no_entry
```

Description

Use this option to set the entry point field to zero for produced ELF files.

See also

--*entry*, page 306.

Project>Options>Linker>Library>Override default program entry

--no_fragments

Syntax `--no_fragments`

Description Use this option to disable section fragment handling. Normally, the toolset uses IAR proprietary information for transferring section fragment information to the linker. The linker uses this information to remove unused code and data, and further minimize the size of the executable image. Use this option to disable the removal of fragments of sections, instead including or not including each section in its entirety, usually resulting in a larger application.

See also *Keeping symbols and sections*, page 111.

To set this option, use **Project>Options>Linker>Extra Options**

--no_free_heap

Syntax `--no_free_heap`

Description Use this option to use the smallest possible heap implementation. Because this heap does not support `free` or `realloc`, it is only suitable for applications that in the startup phase allocate heap memory for various buffers, etc, and for applications that never deallocate memory.

Project>Options>General Options>Library Options 2>Heap selection

--no_inline

Syntax `--no_inline func[,func...]`

Parameters

func	The name of a function symbol

Description Use this option to exclude some functions from small function inlining.

See also *--inline*, page 309.

To set this option, use **Project>Options>Linker>Extra Options**.

--no_library_search

Syntax `--no_library_search`

Description

Use this option to disable the automatic runtime library search. This option turns off the automatic inclusion of the correct standard libraries. This is useful, for example, if the application needs a user-built standard library, etc.

Note: The option disables all steps of the automatic library selection, some of which might need to be reproduced if you are using the standard libraries. Use the `--log libraries` linker option together with automatic library selection enabled to determine which the steps are.

Project>Options>Linker>Library>Automatic runtime library selection

--no_locals

Syntax `--no_locals`

Description

Use this option to remove local symbols from the ELF executable image.

Note: This option does not remove any local symbols from the DWARF information in the executable image.

Project>Options>Linker>Output

--no_range_reservations

Syntax `--no_range_reservations`

Description

Normally, the linker reserves any ranges used by absolute symbols with a non-zero size, excluding them from consideration for `place in` commands.

When this option is used, these reservations are disabled, and the linker is free to place sections in such a way as to overlap the extent of absolute symbols.

To set this option, use **Project>Options>Linker>Extra Options**.

--no_remove

Syntax

`--no_remove`

Description

When this option is used, unused sections are not removed. In other words, each module that is included in the executable image contains all its original sections.

See also

Keeping symbols and sections, page 111.

To set this option, use **Project>Options>Linker>Extra Options**.

--no_vfe

Syntax

`--no_vfe`

Description

Use this option to disable the Virtual Function Elimination optimization. All virtual functions in all classes with at least one instance will be kept, and Runtime Type Information data will be kept for all polymorphic classes. Also, no warning message will be issued for modules that lack VFE information.

See also

--vfe, page 324 and *Virtual function elimination*, page 121.

To set related options, choose:

Project>Options>Linker>Optimizations>PerformC++ Virtual Function Elimination

--no_warnings

Syntax

`--no_warnings`

Description

By default, the linker issues warning messages. Use this option to disable all warning messages.

This option is not available in the IDE.

--no_wrap_diagnostics

Syntax

```
--no_wrap_diagnostics
```

Description

By default, long lines in diagnostic messages are broken into several lines to make the message easier to read. Use this option to disable line wrapping of diagnostic messages.

This option is not available in the IDE.

--only_stdout

Syntax

```
--only_stdout
```

Description

Use this option to make the linker use the standard output stream (`stdout`), and messages that are normally directed to the error output stream (`stderr`).

This option is not available in the IDE.

--output, -o

Syntax

```
--output {filename|directory}
-o {filename|directory}
```

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

Description

By default, the object executable image produced by the linker is located in a file with the name `a.out`. Use this option to explicitly specify a different output filename, which by default will have the filename extension `out`.

Project>Options>Linker>Output>Output file

--place_holder

Syntax

```
--place_holder symbol[,size[,section[,alignment]]]
```

Parameters

symbol	The name of the symbol to create
size	Size in ROM. Default is 4 bytes

section	Section name to use. Default is `.text`
alignment	Alignment of section. Default is `1`

Description

Use this option to reserve a place in ROM to be filled by some other tool, for example, a checksum calculated by `ielftool`. Each use of this linker option results in a section with the specified name, size, and alignment. The symbol can be used by your application to refer to the section.

Note: Like any other section, sections created by the `--place_holder` option will only be included in your application if the section appears to be needed. The `--keep` linker option, or the `keep` linker directive can be used for forcing such section to be included.

See also

IAR utilities, page 483.

To set this option, use **Project>Options>Linker>Extra Options**

--preconfig

Syntax

`--preconfig filename`

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to make the linker read the specified file before reading the linker configuration file.

To set this option, use **Project>Options>Linker>Extra Options**.

--printf_multibytes

Syntax

`--printf_multibytes`

Description

Use this option to make the linker automatically select a `printf` formatter that supports multibytes.

Project>Options>General Options>Library options 1>Printf formatter

--redirect

Syntax `--redirect from_symbol=to_symbol`

Parameters

from_symbol	The name of the source symbol
to_symbol	The name of the destination symbol

Description Use this option to change references to an external symbol so that they refer to another symbol.

Note: Redirection will normally not affect references within a module.

To set this option, use **Project>Options>Linker>Extra Options**

--remarks

Syntax `--remarks`

Description The least severe diagnostic messages are called remarks. A remark indicates a source code construct that may cause strange behavior in the generated code. By default, the linker does not generate remarks. Use this option to make the linker generate remarks.

See also *Severity levels*, page 249.

Project>Options>Linker>Diagnostics>Enable remarks

--scanf_multibytes

Syntax `--scanf_multibytes`

Description Use this option to make the linker automatically select a `scanf` formatter that supports multibytes.

Project>Options>General Options>Library options 1>Scanf formatter

--search, -L

Syntax

`--search path`

`-L path`

Parameters

path	A path to a directory where the linker should search for object and library files.

Description

Use this option to specify more directories for the linker to search for object and library files in.

By default, the linker searches for object and library files only in the working directory. Each use of this option on the command line adds another search directory.

See also

The linking process in detail, page 91.

This option is not available in the IDE.

--silent

Syntax

`--silent`

Description

By default, the linker issues introductory messages and a final statistics report. Use this option to make the linker operate without sending these messages to the standard output stream (normally the screen).

This option does not affect the display of error and warning messages.

This option is not available in the IDE.

--small_math

Syntax

`--small_math`

Description

Use this option to use smaller versions of the math libraries (but less accurate) than the default versions.

See also

Math functions, page 141.

Project>Options>General Options>Library Options 1>Math functions

--stack_usage_control

Syntax `--stack_usage_control=`*`filename`*

Parameters See *Rules for specifying a filename or directory as parameters*, page 252.

Description Use this option to specify a stack usage control file. This file controls stack usage analysis, or provides more stack usage information for modules or functions. You can use this option multiple times to specify multiple stack usage control files. If no filename extension is specified, the extension `suc` is used.

Using this option enables stack usage analysis in the linker.

See also *Stack usage analysis*, page 99.

Project>Options>Linker>Advanced>Control file

--strip

Syntax `--strip`

Description By default, the linker retains the debug information from the input object files in the output executable image. Use this option to remove that information.

To set related options, choose:

Project>Options>Linker>Output>Include debug information in output

--text_out

Syntax `--text_out{utf8|utf16le|utf16be|locale}`

Parameters

`utf8`	Uses the UTF-8 encoding
`utf16le`	Uses the UTF-16 little-endian encoding
`utf16be`	Uses the UTF-16 big-endian encoding
`locale`	Uses the system locale encoding

Description

Use this option to specify the encoding to be used when generating a text output file.

The default for the linker list files is to use the same encoding as the main source file. The default for all other text files is UTF-8 with a Byte Order Mark (BOM).

If you want text output in UTF-8 encoding without BOM, you can use the option `--no_bom` as well.

See also

--*no_bom*, page 314 and *Text encodings*, page 246.

Project>Options>Linker>Encodings>Text output file encoding

--threaded_lib

Syntax

`--threaded_lib`

Description

Use this option to automatically configure the runtime library for use with threads.

Project>Options>General Options>Library Configuration>Enable thread support in library

--timezone_lib

Syntax

`--timezone_lib`

Description

Use this option to enable the time zone and daylight savings time functionality in the DLIB library.

Note: You need to implement the time zone functionality.

See also

__getzone, page 150.

To set this option, use **Project>Option>Linker>Extra Options**.

--use_full_std_template_names

Syntax

`--use_full_std_template_names`

Description

In the unmangled names of C++ entities, the linker by default uses shorter names for some classes. For example, `"std::string"` instead of `"std::basic_string<char,`

std::char_traits<char>,std::allocator<char>>". Use this option to make the linker instead use the full, unabbreviated names.

This option is not available in the IDE.

--utf8_text_in

Syntax

```
--utf8_text_in
```

Description

Use this option to specify that the linker shall use the UTF-8 encoding when reading a text input file with no Byte Order Mark (BOM).

Note: This option does not apply to source files.

See also

Text encodings, page 246.

Project>Options>Linker>Encodings>Default input file encoding

--version

Syntax

```
--version
```

Description

Use this option to make the linker send version information to the console and then exit.

This option is not available in th IDE.

--vfe

Syntax

```
--vfe=[forced]
```

Parameters

forced	Performs Virtual Function Elimination even if one or more modules lack the needed virtual function elimination information.

Description

By default, Virtual Function Elimination is always performed but requires that all object files contain the necessary virtual function elimination information. Use `--vfe=forced` to perform Virtual Function Elimination even if one or more modules do not have the necessary information.

Forcing the use of Virtual Function Elimination can be unsafe if some of the modules that lack the needed information perform virtual function calls or use dynamic Runtime Type Information.

See also

--*no_vfe*, page 317 and *Virtual function elimination*, page 121.

To set related options, choose:

Project>Options>Linker>Optimizations>Perform C++ Virtual Function Elimination

--warnings_affect_exit_code

Syntax

```
--warnings_affect_exit_code
```

Description

By default, the exit code is not affected by warnings, because only errors produce a non-zero exit code. With this option, warnings will also generate a non-zero exit code.

This option is not available in the IDE.

--warnings_are_errors

Syntax

```
--warnings_are_errors
```

Description

Use this option to make the linker treat all warnings as errors. If the linker encounters an error, no executable image is generated. Warnings that have been changed into remarks are not treated as errors.

Note: Any diagnostic messages that have been reclassified as warnings by the option `--diag_warning` will also be treated as errors when `--warnings_are_errors` is used.

See also

--*diag_warning*, page 265 and --*diag_warning*, page 305.

Project>Options>Linker>Diagnostics>Treat all warnings as errors

--whole_archive

Syntax

```
--whole_archive filename
```

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

Description

Use this option to make the linker treat every object file in the archive as if it was specified on the command line. This is useful when an archive contains root content that is always included from an object file (filename extension `o`), but only included from an archive if some entry from the module is referred to.

Example

If `archive.a` contains the object files `file1.o`, `file2.o`, and `file3.o`, using `--whole_archive archive.a` is equivalent to specifying `file1.o file2.o file3.o`.

See also

Keeping modules, page 111.

To set this option, use **Project>Options>Linker>Extra Options**

Data representation

- Alignment
- Basic data types—integer types
- Basic data types—floating-point types
- Pointer types
- Structure types
- Type qualifiers
- Data types in C++

See the chapter *Efficient coding for embedded applications* for information about which data types provide the most efficient code for your application.

Alignment

Every C data object has an alignment that controls how the object can be stored in memory. Should an object have an alignment of, for example, 4, it must be stored on an address that is divisible by 4.

The reason for the concept of alignment is that some processors have hardware limitations for how the memory can be accessed.

Assume that a processor can read 4 bytes of memory using one instruction, but only when the memory read is placed on an address divisible by 4. Then, 4-byte objects, such as `long` integers, will have alignment 4.

Another processor might only be able to read 2 bytes at a time—in that environment, the alignment for a 4-byte `long` integer might be 2.

A structure type will have the same alignment as the structure member with the most strict alignment. To decrease the alignment requirements on the structure and its members, use `#pragma pack`.

All data types must have a size that is a multiple of their alignment. Otherwise, only the first element of an array would be guaranteed to be placed in accordance with the alignment requirements. This means that the compiler might add pad bytes at the end of the structure. For more information about pad bytes, see *Packed structure types*, page 336.

Note: With the `#pragma data_alignment` directive, you can increase the alignment demands on specific variables.

See also the Standard C file `stdalign.h`.

ALIGNMENT ON THE RH850 MICROCONTROLLER

The RH850 microcontroller can access 4-byte objects using a single assembler instruction only when the object is stored at an address divisible by 4. For the same reason, 2-byte objects must be stored at addresses divisible by 2.

To enable 8-byte alignment for the data types `long long` and `double`, use the compiler option `--enable_8_byte_alignment`.

Basic data types—integer types

The compiler supports both all Standard C basic data types and some additional types.

These topics are covered:

INTEGER TYPES—AN OVERVIEW

This table gives the size and range of each integer data type:

Data type	Size	Range	Alignment
`bool`	8 bits	0 to 1	1
`char`	8 bits	0 to 255	1
`signed char`	8 bits	-128 to 127	1
`unsigned char`	8 bits	0 to 255	1
`signed short`	16 bits	-32768 to 32767	2

Table 27: Integer types

Data type	Size	Range	Alignment
unsigned short	16 bits	0 to 65535	2
signed int	32 bits	-2^{31} to $2^{31}-1$	4
unsigned int	32 bits	0 to $2^{32}-1$	4
signed long	32 bits	-2^{31} to $2^{31}-1$	4
unsigned long	32 bits	0 to $2^{32}-1$	4
signed long long	64 bits	-2^{63} to $2^{63}-1$	4 or 8
unsigned long long	64 bits	0 to $2^{64}-1$	4 or 8

Table 27: Integer types (Continued)

Signed variables are represented using the two's complement form.

BOOL

The `bool` data type is supported by default in the C++ language. If you have enabled language extensions, the `bool` type can also be used in C source code if you include the file `stdbool.h`. This will also enable the boolean values `false` and `true`.

THE ENUM TYPE

The compiler will use the smallest type required to hold `enum` constants, preferring `signed` rather than `unsigned`.

When IAR Systems language extensions are enabled, and in C++, the `enum` constants and types can also be of the type `long`, `unsigned long`, `long long`, or `unsigned long long`.

To make the compiler use a larger type than it would automatically use, define an `enum` constant with a large enough value. For example:

```
/* Disables usage of the char type for enum */
enum Cards{Spade1, Spade2,
           DontUseChar=257};
```

See also the C++ `enum struct` syntax.

THE CHAR TYPE

The `char` type is by default unsigned in the compiler, but the `--char_is_signed` compiler option allows you to make it signed.

Note: The library is compiled with the `char` type as unsigned.

THE WCHAR_T TYPE

The `wchar_t` data type is 4 bytes and the encoding used for it is UTF-32.

THE CHAR16_T TYPE

The `char16_t` data type is 2 bytes and the encoding used for it is UTF-16.

THE CHAR32_T TYPE

The `char32_t` data type is 4 bytes and the encoding used for it is UTF-32.

BITFIELDS

In Standard C, `int`, `signed int`, and `unsigned int` can be used as the base type for integer bitfields. In standard C++, and in C when language extensions are enabled in the compiler, any integer or enumeration type can be used as the base type. It is implementation defined whether a plain integer type (`char`, `short`, `int`, etc) results in a signed or unsigned bitfield.

In the IAR C/C++ Compiler for RH850, plain integer types are treated as signed.

Bitfields in expressions are treated as `int` if `int` can represent all values of the bitfield. Otherwise, they are treated as the bitfield base type.

Each bitfield is placed in the next suitably aligned container of its base type that has enough available bits to accommodate the bitfield. Within each container, the bitfield is placed in the first available byte or bytes, taking the byte order into account. Note that containers can overlap if needed, as long as they are suitably aligned for their type.

In addition, the compiler supports an alternative bitfield allocation strategy (disjoint types), where bitfield containers of different types are not allowed to overlap. Using this allocation strategy, each bitfield is placed in a new container if its type is different from that of the previous bitfield, or if the bitfield does not fit in the same container as the previous bitfield. Within each container, the bitfield is placed from the least significant bit to the most significant bit (disjoint types) or from the most significant bit to the least significant bit (reverse disjoint types). This allocation strategy will never use less space than the default allocation strategy (joined types), and can use significantly more space when mixing bitfield types.

Use the `#pragma bitfields` directive to choose which bitfield allocation strategy to use, see *bitfields*, page 361.

Assume this example:

```
struct BitfieldExample
{
  uint32_t a : 12;
  uint16_t b : 3;
  uint16_t c : 7;
  uint8_t  d;
};
```

The example in the joined types bitfield allocation strategy

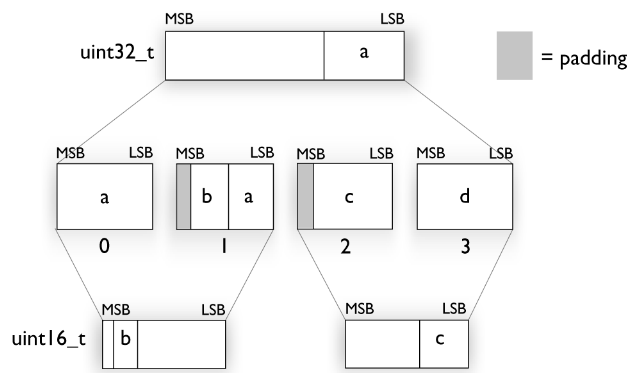
To place the first bitfield, `a`, the compiler allocates a 32-bit container at offset `0` and puts `a` into the first and second bytes of the container.

For the second bitfield, `b`, a 16-bit container is needed and because there are still four bits free at offset `0`, the bitfield is placed there.

For the third bitfield, `c`, as there is now only one bit left in the first 16-bit container, a new container is allocated at offset `2`, and `c` is placed in the first byte of this container.

The fourth member, `d`, can be placed in the next available full byte, which is the byte at offset `3`.

Each bitfield is allocated starting from the least significant free bit of its container to ensure that it is placed into bytes from left to right.



The example in the disjoint types bitfield allocation strategy

To place the first bitfield, `a`, the compiler allocates a 32-bit container at offset `0` and puts `a` into the least significant 12 bits of the container.

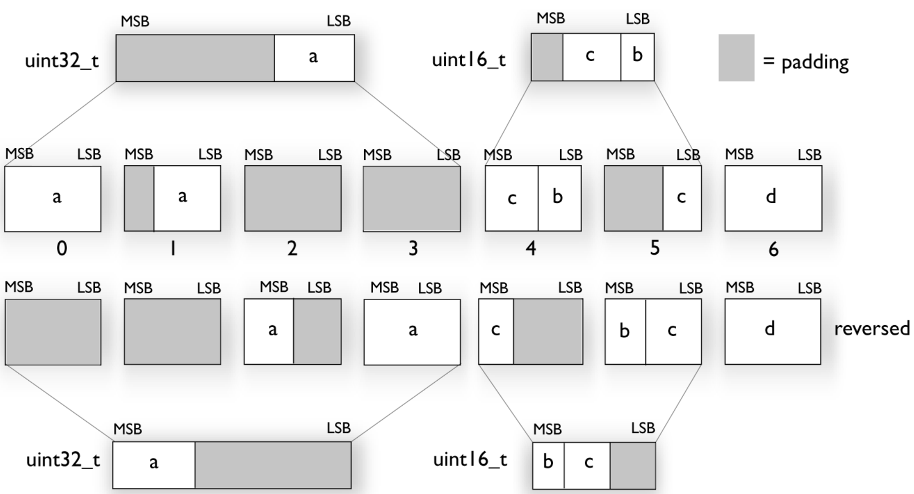
To place the second bitfield, `b`, a new container is allocated at offset `4`, because the type of the bitfield is not the same as that of the previous one. `b` is placed into the least significant three bits of this container.

The third bitfield, `c`, has the same type as `b` and fits into the same container.

The fourth member, `d`, is allocated into the byte at offset `6`. `d` cannot be placed into the same container as `b` and `c` because it is not a bitfield, it is not of the same type, and it would not fit.

When using reverse order (reverse disjoint types), each bitfield is instead placed starting from the most significant bit of its container.

This is the layout of `bitfield_example`:



Basic data types—floating-point types

In the IAR C/C++ Compiler for RH850, floating-point values are represented in standard IEC 60559 format. The sizes for the different floating-point types are:

Type	Size if double=32	Size if double=64	Alignment
`float`	32 bits	32 bits	4
`double`	32 bits	64 bits (default)	4 or 8
`long double`	32 bits	64 bits (default)	4 or 8

Table 28: Floating-point types

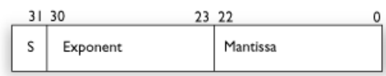
Note: The size of `double` and `long double` depends on the `--double={32|64}` option, see *--double*, page 267. The type `long double` uses the same precision as `double`.

FLOATING-POINT ENVIRONMENT

Exception flags are not supported. The `feraiseexcept` function does not raise any exceptions.

32-BIT FLOATING-POINT FORMAT

The representation of a 32-bit floating-point number as an integer is:



The exponent is 8 bits, and the mantissa is 23 bits.

The value of the number is:

$(-1)^{S} * 2^{(\text{Exponent}-127)} * 1.\text{Mantissa}$

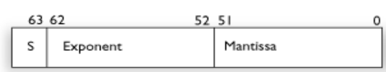
The range of the number is at least:

`±1.18E-38 to ±3.39E+38`

The precision of the float operators (`+`, `-`, `*`, and `/`) is approximately 7 decimal digits.

64-BIT FLOATING-POINT FORMAT

The representation of a 64-bit floating-point number as an integer is:



The exponent is 11 bits, and the mantissa is 52 bits.

The value of the number is:

$(-1)^{S} * 2^{(\text{Exponent}-1023)} * 1.\text{Mantissa}$

The range of the number is at least:

`±2.23E-308 to ±1.79E+308`

The precision of the float operators (`+`, `-`, `*`, and `/`) is approximately 15 decimal digits.

REPRESENTATION OF SPECIAL FLOATING-POINT NUMBERS

This list describes the representation of special floating-point numbers:

- Zero is represented by zero mantissa and exponent. The sign bit signifies positive or negative zero.
- Infinity is represented by setting the exponent to the highest value and the mantissa to zero. The sign bit signifies positive or negative infinity.
- Not a number (`NaN`) is represented by setting the exponent to the highest positive value and the mantissa to a non-zero value. The value of the sign bit is ignored.

- Subnormal numbers are used for representing values smaller than what can be represented by normal values. The drawback is that the precision will decrease with smaller values. The exponent is set to 0 to signify that the number is subnormal, even though the number is treated as if the exponent was 1. Unlike normal numbers, subnormal numbers do not have an implicit 1 as the most significant bit (the MSB) of the mantissa. The value of a subnormal number is:

  $(-1)^{S} * 2^{(1-BIAS)} * 0.Mantissa$

  where `BIAS` is 127.

Note: The floating-point unit (FPU) does not support subnormal numbers. Instead, operations that should have resulted in a subnormal number return zero.

Pointer types

The compiler has two basic types of pointers: function pointers and data pointers.

FUNCTION POINTERS

The size of function pointers is always 32 bits, and they can address the entire memory.

DATA POINTERS

The size of data pointers is always 32 bits, and they can address the entire memory.

CASTING

Casts between pointers have these characteristics:

- Casting a *value* of an integer type to a pointer of a smaller type is performed by truncation
- Casting a value of an unsigned integer type to a pointer of a larger type is performed by zero extension
- Casting a value of a signed integer type to a pointer of a larger type is performed by sign extension
- Casting a pointer type to a smaller integer type is performed by truncation
- Casting a *pointer type* to a larger integer type is performed by zero extension
- Casting a *data pointer* to a function pointer and vice versa is illegal
- Casting a *function pointer* to an integer type gives an undefined result

size_t

`size_t` is the unsigned integer type of the result of the `sizeof` operator. In the IAR C/C++ Compiler for RH850, the type used for `size_t` is `unsigned int`.

ptrdiff_t

`ptrdiff_t` is the signed integer type of the result of subtracting two pointers. In the IAR C/C++ Compiler for RH850, the type used for `ptrdiff_t` is the signed integer variant of the `size_t` type.

intptr_t

`intptr_t` is a signed integer type large enough to contain a `void *`. In the IAR C/C++ Compiler for RH850, the type used for `intptr_t` is `signed int`.

uintptr_t

`uintptr_t` is equivalent to `intptr_t`, with the exception that it is unsigned.

Structure types

The members of a `struct` are stored sequentially in the order in which they are declared: the first member has the lowest memory address.

ALIGNMENT OF STRUCTURE TYPES

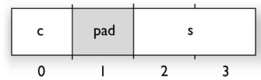
The `struct` and `union` types have the same alignment as the member with the highest alignment requirement—this alignment requirement also applies to a member that is a structure. To allow arrays of aligned structure objects, the size of a `struct` is adjusted to an even multiple of the alignment.

GENERAL LAYOUT

Members of a `struct` are always allocated in the order specified in the declaration. Each member is placed in the `struct` according to the specified alignment (offsets).

```
struct First
{
  char c;
  short s;
} s;
```

This diagram shows the layout in memory:



The alignment of the structure is 2 bytes, and a pad byte must be inserted to give `short s` the correct alignment.

PACKED STRUCTURE TYPES

The `#pragma pack` directive is used for relaxing the alignment requirements of the members of a structure. This changes the layout of the structure. The members are placed in the same order as when declared, but there might be less pad space between members.

Note: Accessing an object that is not correctly aligned requires code that is both larger and slower. If such structure members are accessed many times, it is usually better to construct the correct values in a `struct` that is not packed, and access this `struct` instead.

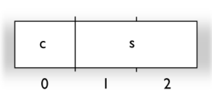
Special care is also needed when creating and using pointers to misaligned members. For direct access to misaligned members in a packed `struct`, the compiler will emit the correct (but slower and larger) code when needed. However, when a misaligned member is accessed through a pointer to the member, the normal (smaller and faster) code is used. In the general case, this will not work, because the normal code might depend on the alignment being correct.

This example declares a packed structure:

```
#pragma pack(1)
struct S
{
  char c;
  short s;
};

#pragma pack()
```

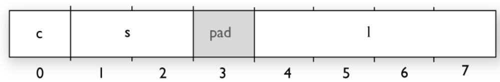
The structure `S` has this memory layout:



The next example declares a new non-packed structure, `S2`, that contains the structure `s` declared in the previous example:

```
struct S2
{
  struct S s;
  long l;
};
```

The structure `S2` has this memory layout



The structure `S` will use the memory layout, size, and alignment described in the previous example. The alignment of the member `l` is 4, which means that alignment of the structure `S2` will become 4.

For more information, see *Alignment of elements in a structure*, page 222.

Type qualifiers

According to the C standard, `volatile` and `const` are type qualifiers.

DECLARING OBJECTS VOLATILE

By declaring an object `volatile`, the compiler is informed that the value of the object can change beyond the compiler's control. The compiler must also assume that any accesses can have side effects—therefore all accesses to the `volatile` object must be preserved.

There are three main reasons for declaring an object `volatile`:

- Shared access—the object is shared between several tasks in a multitasking environment
- Trigger access—as for a memory-mapped SFR where the fact that an access occurs has an effect
- Modified access—where the contents of the object can change in ways not known to the compiler.

Definition of access to volatile objects

The C standard defines an abstract machine, which governs the behavior of accesses to `volatile` declared objects. In general and in accordance to the abstract machine:

- The compiler considers each read and write access to an object declared `volatile` as an access

- The unit for the access is either the entire object or, for accesses to an element in a composite object—such as an array, struct, class, or union—the element. For example:

  ```
  char volatile a;
  a = 5;    /* A write access */
  a += 6;  /* First a read then a write access */
  ```

- An access to a bitfield is treated as an access to the underlying type
- Adding a `const` qualifier to a `volatile` object will make write accesses to the object impossible. However, the object will be placed in RAM as specified by the C standard.

However, these rules are not detailed enough to handle the hardware-related requirements. The rules specific to the IAR C/C++ Compiler for RH850 are described below.

Rules for accesses

In the IAR C/C++ Compiler for RH850, accesses to `volatile` declared objects are subject to these rules:

- All accesses are preserved
- All accesses are complete, that is, the whole object is accessed
- All accesses are performed in the same order as given in the abstract machine
- All accesses are atomic, that is, they cannot be interrupted.

The compiler adheres to these rules for

DECLARING OBJECTS VOLATILE AND CONST

If you declare a `volatile` object `const`, it will be write-protected but it will still be stored in RAM memory as the C standard specifies.

To store the object in read-only memory instead, but still make it possible to access it as a `const volatile` object, define the variable like this:

```
const volatile int x @ "FLASH";
```

The compiler will generate the read/write section `FLASH`. That section should be placed in ROM and is used for manually initializing the variables when the application starts up.

Thereafter, the initializers can be reflashed with other values at any time.

DECLARING OBJECTS CONST

The `const` type qualifier is used for indicating that a data object, accessed directly or via a pointer, is non-writable. A pointer to `const` declared data can point to both constant and non-constant objects. It is good programming practice to use `const` declared pointers whenever possible because this improves the compiler's possibilities to optimize the generated code and reduces the risk of application failure due to erroneously modified data.

Static and global objects declared `const` and located in all memory types except saddr are allocated in ROM.

For `__saddr`, the objects are allocated in RAM and initialized by the runtime system at startup.

In C++, objects that require runtime initialization cannot be placed in ROM.

Data types in C++

In C++, all plain C data types are represented in the same way as described earlier in this chapter. However, if any C++ features are used for a type, no assumptions can be made concerning the data representation. This means, for example, that it is not supported to write assembler code that accesses class members.

Extended keywords

- General syntax rules for extended keywords
- Summary of extended keywords
- Descriptions of extended keywords
- Supported GCC attributes

For information about the address ranges of the different memory areas, see the chapter *Section reference*.

General syntax rules for extended keywords

The compiler provides a set of attributes that can be used on functions or data objects to support specific features of the RH850 microcontroller. There are two types of attributes—*type attributes* and *object attributes*:

- Type attributes affect the *external functionality* of the data object or function
- Object attributes affect the *internal functionality* of the data object or function.

The syntax for the keywords differs slightly depending on whether it is a type attribute or an object attribute, and whether it is applied to a data object or a function.

For more information about each attribute, see *Descriptions of extended keywords*, page 346. For information about how to use attributes to modify data, see the chapter *Data storage*.

Note: The extended keywords are only available when language extensions are enabled in the compiler.

In the IDE, language extensions are enabled by default.

Use the `-e` compiler option to enable language extensions. See *-e*, page 267.

TYPE ATTRIBUTES

Type attributes define how a function is called, or how a data object is accessed. This means that if you use a type attribute, it must be specified both when a function or data object is defined and when it is declared.

You can either place the type attributes explicitly in your declarations, or use the pragma directive `#pragma type_attribute`.

Type attributes can be further divided into *memory type attributes* and *general type attributes*. Memory type attributes are referred to as simply *memory attributes* in the rest of the documentation.

Memory attributes

A memory attribute corresponds to a certain logical or physical memory in the microcontroller.

Available *data memory attributes*:

`__near`, `__brel`, `__brel23`, `__huge`, `__saddr`.

Data objects, functions, and destinations of pointers or C++ references always have a memory attribute. If no attribute is explicitly specified in the declaration or by the pragma directive `#pragma type_attribute`, an appropriate default attribute is implicitly used by the compiler. You can specify one memory attribute for each level of pointer indirection.

General type attributes

Available *function type attributes* (affect how the function should be called):

`__callt`, `__syscall`, `__fetrap`, `__interrupt`, `__monitor`, `__task`, `__trap`

Available *data type attributes*:

`__no_bit_access`

You can specify as many type attributes as required for each level of pointer indirection.

Syntax for type attributes used on data objects

If you select the *uniform attribute syntax*, data type attributes use the same syntax rules as the type qualifiers `const` and `volatile`.

If not, data type attributes use almost the same syntax rules as the type qualifiers `const` and `volatile`. For example:

```
__brel int i;
int __brel j;
```

Both `i` and `j` are placed in brel memory.

Unlike `const` and `volatile`, when a type attribute is used before the type specifier in a derived type, the type attribute applies to the object, or typedef itself, except in structure member declarations.

```
int * __brel p;        /* pointer in brel memory */
```

```
__brel int * p;        /* pointer in brel memory */
```

The third case is interpreted differently when uniform attribute syntax is selected. If so, it is equivalent to the first case, just as would be the case if `const` or `volatile` were used correspondingly.

In all cases, if a memory attribute is not specified, an appropriate default memory type is used, which depends on the data model in use.

Using a type definition can sometimes make the code clearer:

```
typedef __brel int d16_int;
d16_int *q1;
```

`d16_int` is a typedef for integers in brel memory. The variable `q1` can point to such integers.

You can also use the `#pragma type_attributes` directive to specify type attributes for a declaration. The type attributes specified in the pragma directive are applied to the data object or typedef being declared.

```
#pragma type_attribute=__brel
int * q2;
```

The variable `q2` is placed in brel memory.

For more information about the uniform attribute syntax, see --*uniform_attribute_syntax*, page 290 and --*no_uniform_attribute_syntax*, page 281.

Syntax for type attributes used on functions

The syntax for using type attributes on functions differs slightly from the syntax of type attributes on data objects. For functions, the attribute must be placed either in front of the return type, or inside the parentheses for function pointers, for example:

```
__interrupt void my_handler(void);
```

or

```
void (__interrupt * my_fp)(void);
```

You can also use `#pragma type_attribute` to specify the function type attributes:

```
#pragma type_attribute=__interrupt
void my_handler(void);

#pragma type attribute=__interrupt
typedef void my_fun_t(void);
my_fun_t * my_fp;
```

OBJECT ATTRIBUTES

Normally, object attributes affect the internal functionality of functions and data objects, but not directly how the function is called or how the data is accessed. This means that an object attribute does not normally need to be present in the declaration of an object.

These object attributes are available:

- Object attributes that can be used for variables:

  `__no_alloc`, `__no_alloc16`, `__no_alloc_str`, `__no_alloc_str16`, `__no_init`, `__ro_placement`
- Object attributes that can be used for functions and variables:

  `location`, `@`, `__root`, `__weak`
- Object attributes that can be used for functions:

  `__ei_int`, `__fe_int`, `__flat`, `__intrinsic`, `__noreturn`, `vector`

You can specify as many object attributes as required for a specific function or data object.

For more information about `location` and `@`, see *Controlling data and function placement in memory*, page 224. For more information about `vector`, see *vector*, page 383.

Syntax for object attributes

The object attribute must be placed in front of the type. For example, to place `myarray` in memory that is not initialized at startup:

```
__no_init int myarray[10];
```

The `#pragma object_attribute` directive can also be used. This declaration is equivalent to the previous one:

```
#pragma object_attribute=__no_init
int myarray[10];
```

Note: Object attributes cannot be used in combination with the `typedef` keyword.

Summary of extended keywords

This table summarizes the extended keywords:

Extended keyword	Description
`__brel`	Controls the storage of data objects
`__brel23`	Controls the storage of data objects
`__callt`	Controls the storage of functions
`__cc_version1`	Reserved for compiler internal use only
`__code`	Reserved for compiler internal use only
`__db_int`	Reserved for compiler internal use only
`__ei_int`	Makes an interrupt function an `EI` level interrupt
`__fe_int`	Makes an interrupt function an `FE` level interrupt
`__fetrap`	Supports fetrap functions
`__flat`	Inhibits saving certain processor registers
`__huge`	Controls the storage of data objects
`__interrupt`	Specifies interrupt functions
`__intrinsic`	Reserved for compiler internal use only
`__monitor`	Specifies atomic execution of a function
`__near`	Controls the storage of data objects
`__no_bit_access`	Prevents bit-instruction accessing of data objects
`__no_alloc`, `__no_alloc16`	Makes a constant available in the execution file
`__no_alloc_str`, `__no_alloc_str16`	Makes a string literal available in the execution file
`__no_init`	Places a data object in non-volatile memory
`__noreturn`	Informs the compiler that the function will not return
`__ro_placement`	Places `const volatile` data in read-only memory.
`__root`	Ensures that a function or variable is included in the object code even if unused
`__saddr`	Controls the storage of data objects
`__syscall`	Controls the storage of functions
`__task`	Relaxes the rules for preserving registers
`__trap`	Supports trap functions
`__weak`	Declares a symbol to be externally weakly linked

Table 29: Extended keywords summary

Descriptions of extended keywords

This section gives detailed information about each extended keyword.

__brel

Syntax

See *Syntax for type attributes used on data objects*, page 342.

Description

The `__brel` memory attribute overrides the default storage of variables given by the selected data model and places individual variables and constants in brel memory.

Storage information

- Address range: 64 Kbytes anywhere in RAM and 64 Kbytes anywhere in ROM
- Maximum object size: 65535 bytes.

Example

```
__brel int x;
```

See also

Memory types, page 68.

__brel23

Syntax

See *Syntax for type attributes used on data objects*, page 342.

Description

The `__brel23` memory attribute overrides the default storage of variables given by the selected data model and places individual variables and constants in base-relative (brel) memory using the disp23 addressing mode of `LD` and `ST` instructions.

Storage information

- Address range: 8 Mbytes anywhere in RAM and 8 Mbytes anywhere in ROM. This includes the brel memory area.
- Maximum object size: 8 Mbytes.

Example

```
__brel23 int x;
```

See also

Memory types, page 68.

__callt

Syntax

See *Syntax for type attributes used on functions*, page 343.

Description

Use the `__callt` attribute to place an individual function in the call table.

Storage information

Vector range: 0–63

Example

Declaring a callt function using call table vector `0x25`:

```
#pragma vector=0x25
__callt void my_callt_function(int my_int);
```

If the pragma directive is omitted, the vector will be assigned automatically.

See also

Call table functions, page 80.

__cc_version1

Description

The `__cc_version1` keyword is reserved for compiler internal use only.

__code

Description

The `__code` keyword is reserved for compiler internal use only.

__db_int

Description

The `__db_int` keyword is reserved for compiler internal use only.

__ei_int

Syntax

See *Syntax for object attributes*, page 344.

Description

The `__ei_int` keyword can be used in the definition of an interrupt function to ensure that an `EI` level interrupt function returns correctly. (This is the default interrupt level.)

Example

```
__ei_int __interrupt void my_interrupt_handler(void);
```

See also

Interrupt functions, page 78.

__fe_int

Syntax

See *Syntax for object attributes*, page 344.

Description

The `__fe_int` keyword can be used in the definition of an interrupt function to ensure that an `FE` level interrupt function returns correctly.

Example

```
__fe_int __interrupt void my_interrupt_handler(void);
```

See also

Interrupt functions, page 78.

__fetrap

Syntax

See *Syntax for type attributes used on functions*, page 343.

Description

Use the `__fetrap` keyword to define an fetrap function. Do not specify a vector, the function will automatically be assigned a vector by the system.

Example

```
__fetrap int my_fetrap_function(int a);

...
if (my_fetrap_function(100))
...
```

See also

Trap functions, page 79 and *Calling convention*, page 171.

__flat

Syntax

See *Syntax for object attributes*, page 344.

Description

The `__flat` keyword can be used in the definition of a trap, interrupt, callt, or syscall function to inhibit the generation of code that stores and restores special processor registers at the entry and leave code, respectively.

Note: You should not use this keyword if the system is supposed to handle nested interrupts, or if the trap or call table function could—directly or indirectly—call another trap or call table function.

Example

```
__flat __interrupt void my_int_func(void)
```

See also

Primitives for interrupts, concurrency, and OS-related programming, page 77.

__huge

Syntax

See *Syntax for type attributes used on data objects*, page 342.

Description

The `__huge` memory attribute overrides the default storage of variables given by the selected data model and places individual variables and constants in huge memory.

Storage information

- Address range: Anywhere in memory
- Maximum object size: 4 Gbytes.

Example

```
__huge int x;
```

See also

Memory types, page 68.

__interrupt

Syntax

See *Syntax for type attributes used on functions*, page 343.

Description

The `__interrupt` keyword specifies interrupt functions. To specify one or several interrupt vectors, use the `#pragma vector` directive. The range of the interrupt vectors depends on the device used. It is possible to define an interrupt function without a vector, but then the compiler will not generate an entry in the interrupt vector table.

The __interrupt keyword can also be used without a `#pragma vector` directive to replace default exception handlers with proper exception handlers.

An interrupt function must have a `void` return type and cannot have any parameters.

The header file `io`*`device`*`.h`, where *`device`* corresponds to the selected device, contains predefined names for the existing interrupt vectors. The vector number specifies the `EI` interrupt channel number (not the offset in bytes).

To make sure that the interrupt handler executes as fast as possible, you should compile it with `-Ohs`, or use `#pragma optimize=speed` if the module is compiled with another optimization goal.

Example

```
#pragma vector=0x14
__interrupt void my_interrupt_handler(void);
```

See also

Interrupt functions, page 78, *vector*, page 383,.

__intrinsic

Description

The `__intrinsic` keyword is reserved for compiler internal use only.

__monitor

Syntax

See *Syntax for type attributes used on functions*, page 343.

Description — The `__monitor` keyword causes interrupts to be disabled during execution of the function. This allows atomic operations to be performed, such as operations on semaphores that control access to resources by multiple processes. A function declared with the `__monitor` keyword is equivalent to any other function in all other respects.

Example

```
__monitor int get_lock(void);
```

See also — *Monitor functions*, page 81. For information about related intrinsic functions, see *__disable_interrupt*, page 391, *__enable_interrupt*, page 391, *__get_interrupt_state*, page 393, and *__set_interrupt_state*, page 398, respectively.

__near

Syntax — See *Syntax for type attributes used on data objects*, page 342.

Description — The `__near` memory attribute overrides the default storage of variables given by the selected data model and places individual variables and constants in near memory.

You can also use the `__near` attribute to create a pointer explicitly pointing to an object located in the near memory.

Storage information

- Address range: `0x0-07FFF and 0xFFFF8000-0xFFFFFFFF` (64 Kbytes)
- Maximum object size: 32 Kbytes.

Example

```
__near int x;
```

See also — *Memory types*, page 68.

__no_bit_access

Syntax — See *Syntax for type attributes used on functions*, page 343.

Description — Data objects declared with the `__no_bit_access` keyword will not be accessed using bit instructions. The main use of this keyword is to declare memory-mapped peripheral units that do not support bit access.

Example

```
__no_bit_access int x;
```

__no_alloc, __no_alloc16

Syntax

See *Syntax for object attributes*, page 344.

Description

Use the `__no_alloc` or `__no_alloc16` object attribute on a constant to make the constant available in the executable file without occupying any space in the linked application.

You cannot access the contents of such a constant from your application. You can take its address, which is an integer offset to the section of the constant. The type of the offset is `unsigned long` when `__no_alloc` is used, and `unsigned short` when `__no_alloc16` is used.

Example

```
__no_alloc const struct MyData my_data @ "XXX" = {...};
```

See also

__no_alloc_str, __no_alloc_str16, page 351.

__no_alloc_str, __no_alloc_str16

Syntax

`__no_alloc_str(`*`string_literal`* `@` *`section`*`)`

and

`__no_alloc_str16(`*`string_literal`* `@` *`section`*`)`

where

`string_literal`	The string literal that you want to make available in the executable file.
`section`	The name of the section to place the string literal in.

Description

Use the `__no_alloc_str` or `__no_alloc_str16` operators to make string literals available in the executable file without occupying any space in the linked application.

The value of the expression is the offset of the string literal in the section. For `__no_alloc_str`, the type of the offset is `unsigned long`. For `__no_alloc_str16`, the type of the offset is `unsigned short`.

Example

```
#define MYSEG "YYY"
#define X(str) __no_alloc_str(str @ MYSEG)

extern void dbg_printf(unsigned long fmt, ...)

#define DBGPRINTF(fmt, ...) dbg_printf(X(fmt), __VA_ARGS__)

void
foo(int i, double d)
{
  DBGPRINTF("The value of i is: %d, the value of d is: %f",i,d);
}
```

Depending on your debugger and the runtime support, this could produce trace output on the host computer.

Note: There is no such runtime support in C-SPY, unless you use an external plugin module.

See also

__no_alloc, __no_alloc16, page 351.

__no_init

Syntax

See *Syntax for object attributes*, page 344.

Description

Use the `__no_init` keyword to place a data object in non-volatile memory. This means that the initialization of the variable, for example at system startup, is suppressed.

Example

```
__no_init int myarray[10];
```

See also

Non-initialized variables, page 238 and *do not initialize directive*, page 439.

__noreturn

Syntax

See *Syntax for object attributes*, page 344.

Description

The `__noreturn` keyword can be used on a function to inform the compiler that the function will not return. If you use this keyword on such functions, the compiler can optimize more efficiently. Examples of functions that do not return are `abort` and `exit`.

Note: At optimization levels Medium or High, the `__noreturn` keyword might cause incorrect call stack debug information at any point where it can be determined that the current function cannot return.

Note: The extended keyword `__noreturn` has the same meaning as the Standard C keyword `_Noreturn` or the macro `noreturn` (if `stdnoreturn.h` has been included) and as the Standard C++ attribute `[[noreturn]]`.

Example

```
__noreturn void terminate(void);
```

__ro_placement

Syntax

See *Syntax for object attributes*, page 344.

Unlike most object attributes, the `__ro_placement` attribute must be specified both when a data object is defined and when it is declared.

Description

The `__ro_placement` attribute specifies that a data object should be placed in read-only memory. There are two cases where you might want to use this object attribute:

- Data objects declared `const volatile` are by default placed in read-write memory. Use the `__ro_placement` object attribute to place the data object in read-only memory instead.
- In C++, a data object declared `const` and that needs dynamic initialization is placed in read-write memory and initialized at system startup. If you use the `__ro_placement` object attribute, the compiler will give an error message if the data object needs dynamic initialization.

You can only use the `__ro_placement` object attribute on `const` objects.

You can use the `__ro_placement` attribute with C++ objects if the compiler can optimize the C++ dynamic initialization of the data objects into static initialization. This is possible only for relatively simple constructors that have been defined in the header files of the relevant class definitions, so that they are visible to the compiler. If the compiler cannot find the constructor, or if the constructor is too complex, an error message will be issued (`Error[Go023]`) and the compilation will fail.

Example

```
__ro_placement const volatile int x = 10;
```

__root

Syntax

See *Syntax for object attributes*, page 344.

Description

A function or variable with the `__root` attribute is kept whether or not it is referenced from the rest of the application, provided its module is included. Program modules are always included and library modules are only included if needed.

Example

```
__root int myarray[10];
```

See also

For more information about root symbols and how they are kept, see *Keeping symbols and sections*, page 111.

__saddr

Syntax

See *Syntax for type attributes used on data objects*, page 342.

Description

The `__saddr` memory attribute overrides the default storage of variables given by the selected data model and places individual variables and constants in short addressing (saddr) memory.

You can also use the `__saddr` attribute to create a pointer explicitly pointing to an object located in the saddr memory.

Storage information

- Address range: From processor register `R30` (`EP`) and 256 bytes onward.
- Maximum object size: 256 bytes (128 bytes for objects that require byte access and 32 bytes for objects that require unsigned byte/half word read access).

Example

```
__saddr int x;
```

See also

Memory types, page 68.

__syscall

Syntax

See *Syntax for type attributes used on functions*, page 343.

Description

Use the `__syscall` attribute to place an individual function in the syscall table.

Storage information

Vector range: 0–255

Example

Declaring a syscall function using table vector `0x25`:

```
#pragma vector=0x25
__syscall void my_syscall_function(int my_int);
```

If the pragma directive is omitted, the vector will be assigned automatically.

See also

Call table functions, page 80.

__task

Syntax

See *Syntax for type attributes used on functions*, page 343.

Description

This keyword allows functions to relax the rules for preserving registers. Typically, the keyword is used on the start function for a task in an RTOS.

By default, functions save the contents of used preserved registers on the stack upon entry, and restore them at exit. Functions that are declared `__task` do not save all registers, and therefore require less stack space.

Because a function declared `__task` can corrupt registers that are needed by the calling function, you should only use `__task` on functions that do not return or call such a function from assembler code.

The function `main` can be declared `__task`, unless it is explicitly called from the application. In real-time applications with more than one task, the root function of each task can be declared `__task`.

Example

```
__task void my_handler(void);
```

__trap

Syntax

See *Syntax for type attributes used on functions*, page 343.

Description

Use the `__trap` keyword to define a trap function. Do not specify a vector, the function will automatically be assigned a vector by the system.

Example

```
__trap int my_trap_function(int a);

...
if (my_trap_function(100))
...
```

See also

Calling convention, page 171 and *Trap functions*, page 79.

__weak

Syntax

See *Syntax for object attributes*, page 344.

Description

Using the `__weak` object attribute on an external declaration of a symbol makes all references to that symbol in the module weak.

Using the `__weak` object attribute on a public definition of a symbol makes that definition a weak definition.

The linker will not include a module from a library solely to satisfy weak references to a symbol, nor will the lack of a definition for a weak reference result in an error. If no definition is included, the address of the object will be zero.

When linking, a symbol can have any number of weak definitions, and at most one non-weak definition. If the symbol is needed, and there is a non-weak definition, this definition will be used. If there is no non-weak definition, one of the weak definitions will be used.

Example

```
extern __weak int foo; /* A weak reference. */

__weak void bar(void)  /* A weak definition. */
{
  /* Increment foo if it was included. */
  if (&foo != 0)
    ++foo;
}
```

Supported GCC attributes

In extended language mode, the IAR C/C++ Compiler also supports a limited selection of GCC-style attributes. Use the `__attribute__ ((`*`attribute-list`*`))` syntax for these attributes.

The following attributes are supported in part or in whole. For more information, see the GCC documentation.

- `alias`
- `aligned`
- `always_inline`
- `constructor`
- `deprecated`
- `noinline`
- `noreturn`
- `packed`
- `pcs` (for IAR type attributes used on functions)
- `section`
- `target` (for IAR object attributes used on functions)

- transparent_union
- unused
- used
- volatile
- weak

Pragma directives

- Summary of pragma directives
- Descriptions of pragma directives

Summary of pragma directives

The #pragma directive is defined by Standard C and is a mechanism for using vendor-specific extensions in a controlled way to make sure that the source code is still portable.

The pragma directives control the behavior of the compiler, for example, how it allocates memory for variables and functions, whether it allows extended keywords, and whether it outputs warning messages.

The pragma directives are always enabled in the compiler.

This table lists the pragma directives of the compiler that can be used either with the `#pragma` preprocessor directive or the `_Pragma()` preprocessor operator:

Pragma directive	Description
`bitfields`	Controls the order of bitfield members.
`calls`	Lists possible called functions for indirect calls.
`call_graph_root`	Specifies that the function is a call graph root.
`constseg`	Places constant variables in a named section.
`core`	Identifies the core in a multicore system.
`cstat_disable`	See the *C-STAT® Static Analysis Guide*.
`cstat_enable`	See the *C-STAT® Static Analysis Guide*.
`cstat_restore`	See the *C-STAT® Static Analysis Guide*.
`cstat_suppress`	See the *C-STAT® Static Analysis Guide*.
`data_alignment`	Gives a variable a higher (more strict) alignment.
`dataseg`	Places variables in a named section.
`default_function_attributes`	Sets default type and object attributes for declarations and definitions of functions.
`default_variable_attributes`	Sets default type and object attributes for declarations and definitions of variables.
`deprecated`	Marks an entity as deprecated.

Table 30: Pragma directives summary

Pragma directive	Description
diag_default	Changes the severity level of diagnostic messages.
diag_error	Changes the severity level of diagnostic messages.
diag_remark	Changes the severity level of diagnostic messages.
diag_suppress	Suppresses diagnostic messages.
diag_warning	Changes the severity level of diagnostic messages.
error	Signals an error while parsing.
function_category	Declares function categories for stack usage analysis.
include_alias	Specifies an alias for an include file.
inline	Controls inlining of a function.
language	Controls the IAR Systems language extensions.
location	Specifies the absolute address of a variable, or places groups of functions or variables in named sections.
message	Prints a message.
no_stack_protect	Disables stack protection for the following function.
object_attribute	Adds object attributes to the declaration or definition of a variable or function.
optimize	Specifies the type and level of an optimization.
pack	Specifies the alignment of structures and union members.
__printf_args	Verifies that a function with a printf-style format string is called with the correct arguments.
public_equ	Defines a public assembler label and gives it a value.
required	Ensures that a symbol that is needed by another symbol is included in the linked output.
rtmodel	Adds a runtime model attribute to the module.
__scanf_args	Verifies that a function with a scanf-style format string is called with the correct arguments.
section	Declares a section name to be used by intrinsic functions.
segment	This directive is an alias for #pragma section.
stack_protect	Forces stack protection for the function that follows.
STDC CX_LIMITED_RANGE	Specifies whether the compiler can use normal complex mathematical formulas or not.

Table 30: Pragma directives summary (Continued)

Pragma directive	Description
STDC FENV_ACCESS	Specifies whether your source code accesses the floating-point environment or not.
STDC FP_CONTRACT	Specifies whether the compiler is allowed to contract floating-point expressions or not.
type_attribute	Adds type attributes to a declaration or to definitions.
unroll	Unrolls loops.
vector	Specifies the vector of an interrupt or call table function.
weak	Makes a definition a weak definition, or creates a weak alias for a function or a variable.

Table 30: Pragma directives summary (Continued)

Note: For portability reasons, see also *Recognized pragma directives (6.10.6)*, page 557.

Descriptions of pragma directives

This section gives detailed information about each pragma directive.

bitfields

Syntax

```
#pragma bitfields=disjoint_types|joined_types|
                  reversed_disjoint_types|reversed|default}
```

Parameters

disjoint_types	Bitfield members are placed from the least significant bit to the most significant bit in the container type. Storage containers of bitfields with different base types will not overlap.
joined_types	Bitfield members are placed depending on the byte order. Storage containers of bitfields will overlap other structure members. For more information, see *Bitfields*, page 330.
reversed_disjoint_types	Bitfield members are placed from the most significant bit to the least significant bit in the container type. Storage containers of bitfields with different base types will not overlap.

`reversed`	This is an alias for `reversed_disjoint_types`.
`default`	Restores the default layout of bitfield members. The default behavior for the compiler is `joined_types`.

Description

Use this pragma directive to control the layout of bitfield members.

Example

```
#pragma bitfields=disjoint_types
/* Structure that uses disjoint bitfield types. */
struct S
{
  unsigned char  error : 1;
  unsigned char  size  : 4;
  unsigned short code  : 10;
};
#pragma bitfields=default /* Restores to default setting. */
```

See also

Bitfields, page 330.

calls

Syntax

`#pragma calls=`*`arg`*`[, `*`arg`*`...]`

Parameters

`arg` can be one of these:

`function`	A declared function
`category`	A string that represents the name of a function category

Description

Use this pragma directive to specify all functions that can be indirectly called in the following statement. This information can be used for stack usage analysis in the linker. You can specify individual functions or function categories. Specifying a category is equivalent to specifying all included functions in that category.

Example

```
void Fun1(), Fun2();

void Caller(void (*fp)(void))
{
#pragma calls = Fun1, Fun2, "Cat1"
  (*fp)();         // Can call Fun1, Fun2, and all
                   // functions in category "Cat1"
}
```

See also *function_category*, page 370 and *Stack usage analysis*, page 99.

call_graph_root

Syntax `#pragma call_graph_root[=category]`

Parameters

category	A string that identifies an optional call graph root category

Description Use this pragma directive to specify that, for stack usage analysis purposes, the immediately following function is a call graph root. You can also specify an optional category. The compiler will usually automatically assign a call graph root category to interrupt and task functions. If you use the `#pragma call_graph_root` directive on such a function you will override the default category. You can specify any string as a category.

Example

```
#pragma call_graph_root="interrupt"
```

See also *Stack usage analysis*, page 99.

constseg

Syntax `#pragma constseg=[__memoryattribute ]{SECTION_NAME|default}`

Parameters

__memoryattribute	An optional memory attribute denoting in what memory the section will be placed; if not specified, default memory is used.
SECTION_NAME	A user-defined section name; cannot be a section name predefined for use by the compiler and linker.
`default`	Uses the default section for constants.

Description Use this pragma directive to place constant variables in a named section. The section name cannot be a section name predefined for use by the compiler and linker. The setting remains active until you turn it off again with the `#pragma constseg=default` directive.

Example

```
#pragma constseg=__brel MY_CONSTANTS
const int factorySettings[] = {42, 15, -128, 0};
#pragma constseg=default
```

core

Syntax

```
#pragma core=n
```

Parameters

n	The ordinal number of one of the cores of your microcontroller (1–7).

Description

By default, all cores in a multicore system use the same interrupt vector table. If one or more cores need to specify their own specific interrupt functions, you must use `#pragma core` to identify the core.

Example

```
#pragma core=2
#pragma vector=INTDMA0_vector
__interrupt void dma( void )
{
}
```

data_alignment

Syntax

```
#pragma data_alignment=expression
```

Parameters

expression	A constant which must be a power of two (1, 2, 4, etc.).

Description

Use this pragma directive to give the immediately following variable a higher (more strict) alignment of the start address than it would otherwise have. This directive can be used on variables with static and automatic storage duration.

When you use this directive on variables with automatic storage duration, there is an upper limit on the allowed alignment for each function, determined by the calling convention used.

Note: Normally, the size of a variable is a multiple of its alignment. The `data_alignment` directive only affects the alignment of the variable's start address, and not its size, and can therefore be used for creating situations where the size is not a multiple of the alignment.

Note: To comply with the ISO C11 standard and later, it is recommended to use the alignment specifier `_Alignas` for C code. To comply with the C++11 standard and later, it is recommended to use the alignment specifier `alignas` for C++ code.

dataseg

Syntax

```
#pragma dataseg=[__memoryattribute]{SECTION_NAME|default}
```

Parameters

`__memoryattribute`	An optional memory attribute denoting in what memory the section will be placed; if not specified, default memory is used.
`SECTION_NAME`	A user-defined section name; cannot be a section name predefined for use by the compiler and linker.
`default`	Uses the default section.

Description

Use this pragma directive to place variables in a named section. The section name cannot be a section name predefined for use by the compiler and linker. The variable will not be initialized at startup, and can for this reason not have an initializer, which means it must be declared `__no_init`. The setting remains active until you turn it off again with the `#pragma dataseg=default` directive.

Example

```
#pragma dataseg=__brel MY_SECTION
__no_init char myBuffer[1000];
#pragma dataseg=default
```

default_function_attributes

Syntax

```
#pragma default_function_attributes=[ attribute...]
```

where *attribute* can be:

```
type_attribute
object_attribute
@ section_name
```

Parameters

`type_attribute`	See *Type attributes*, page 341.
`object_attribute`	See *Object attributes*, page 344.
`@ section_name`	See *Data and function placement in sections*, page 226.

Description

Use this pragma directive to set default section placement, type attributes, and object attributes for function declarations and definitions. The default settings are only used for declarations and definitions that do not specify type or object attributes or location in some other way.

Specifying a `default_function_attributes` pragma directive with no attributes, restores the initial state where no such defaults have been applied to function declarations and definitions.

Example

```
/* Place following functions in section MYSEC" */
#pragma default_function_attributes = @ "MYSEC"
int fun1(int x) { return x + 1; }
int fun2(int x) { return x - 1;
/* Stop placing functions into MYSEC */
#pragma default_function_attributes =
```

has the same effect as:

```
int fun1(int x) @ "MYSEC" { return x + 1; }
int fun2(int x) @ "MYSEC" { return x - 1; }
```

See also

location, page 373.

object_attribute, page 374.

type_attribute, page 381.

default_variable_attributes

Syntax

`#pragma default_variable_attributes=[ `*`attribute`*`...]`

where *`attribute`* can be:

`type_attribute`
`object_attribute`
`@ `*`section_name`*

Parameters

`type_attribute`	See *Type attributes*, page 341.
`object_attributes`	See *Object attributes*, page 344.
`@ `*`section_name`*	See *Data and function placement in sections*, page 226.

Description

Use this pragma directive to set default section placement, type attributes, and object attributes for declarations and definitions of variables with static storage duration. The default settings are only used for declarations and definitions that do not specify type or object attributes or location in some other way.

Specifying a `default_variable_attributes` pragma directive with no attributes restores the initial state of no such defaults being applied to variables with static storage duration.

Example

```
/* Place following variables in section MYSEC" */
#pragma default_variable_attributes = @ "MYSEC"
int var1 = 42;
int var2 = 17;
/* Stop placing variables into MYSEC */
#pragma default_variable_attributes =
```

has the same effect as:

```
int var1 @ "MYSEC" = 42;
int var2 @ "MYSEC" = 17;
```

See also

location, page 373.

object_attribute, page 374.

type_attribute, page 381.

deprecated

Syntax

```
#pragma deprecated=entity
```

Description

If you place this pragma directive immediately before the declaration of a type, variable, function, field, or constant, any use of that type, variable, function, field, or constant will result in a warning.

The `deprecated` pragma directive has the same effect as the C++ attribute `[[deprecated]]`, but is available in C as well.

Example

```
#pragma deprecated
typedef int * intp_t;  // typedef intp_t is deprecated

#pragma deprecated
extern int fun(void);  // function fun is deprecated

#pragma deprecated
struct xx {            // struct xx is deprecated
  int x;
};
```

```
struct yy {
#pragma deprecated
  int y;                // field y is deprecated
};

intp_t fun(void)        // Warning here
{
  struct xx ax;         // Warning here
  struct yy ay;
  fun();                // Warning here
  return ay.y;          // Warning here
}
```

See also

Annex K (*Bounds-checking interfaces*) of the C standard.

diag_default

Syntax

`#pragma diag_default=`*`tag`*`[,`*`tag`*`,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Pe177`.

Description

Use this pragma directive to change the severity level back to the default, or to the severity level defined on the command line by any of the options `--diag_error`, `--diag_remark`, `--diag_suppress`, or `--diag_warnings`, for the diagnostic messages specified with the tags. This level remains in effect until changed by another diagnostic-level pragma directive.

See also

Diagnostics, page 248.

diag_error

Syntax

`#pragma diag_error=`*`tag`*`[,`*`tag`*`,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Pe177`.

Description

Use this pragma directive to change the severity level to `error` for the specified diagnostics. This level remains in effect until changed by another diagnostic-level pragma directive.

See also *Diagnostics*, page 248.

diag_remark

Syntax `#pragma diag_remark=tag[,tag,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Pe177`.

Description Use this pragma directive to change the severity level to `remark` for the specified diagnostic messages. This level remains in effect until changed by another diagnostic-level pragma directive.

See also *Diagnostics*, page 248.

diag_suppress

Syntax `#pragma diag_suppress=tag[,tag,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Pe117`.

Description Use this pragma directive to suppress the specified diagnostic messages. This level remains in effect until changed by another diagnostic-level pragma directive.

See also *Diagnostics*, page 248.

diag_warning

Syntax `#pragma diag_warning=tag[,tag,...]`

Parameters

tag	The number of a diagnostic message, for example, the message number `Pe826`.

Description Use this pragma directive to change the severity level to `warning` for the specified diagnostic messages. This level remains in effect until changed by another diagnostic-level pragma directive.

See also *Diagnostics*, page 248.

error

Syntax `#pragma error message`

Parameters

message	A string that represents the error message.

Description Use this pragma directive to cause an error message when it is parsed. This mechanism is different from the preprocessor directive `#error`, because the `#pragma error` directive can be included in a preprocessor macro using the `_Pragma` form of the directive and only causes an error if the macro is used.

Example

```
#if FOO_AVAILABLE
#define FOO ...
#else
#define FOO _Pragma("error\"Foo is not available\"")
#endif
```

If `FOO_AVAILABLE` is zero, an error will be signaled if the `FOO` macro is used in actual source code.

function_category

Syntax `#pragma function_category=category[, category...]`

Parameters

category	A string that represents the name of a function category.

Description Use this pragma directive to specify one or more function categories that the immediately following function belongs to. When used together with `#pragma calls`, the `function_category` directive specifies the destination for indirect calls for stack usage analysis purposes.

Example `#pragma function_category="Cat1"`

See also *calls*, page 362 and *Stack usage analysis*, page 99.

include_alias

Syntax

```
#pragma include_alias ("orig_header" , "subst_header")
#pragma include_alias (<orig_header> , <subst_header>)
```

Parameters

orig_header	The name of a header file for which you want to create an alias.
subst_header	The alias for the original header file.

Description

Use this pragma directive to provide an alias for a header file. This is useful for substituting one header file with another, and for specifying an absolute path to a relative file.

This pragma directive must appear before the corresponding `#include` directives and `subst_header` must match its corresponding `#include` directive exactly.

Example

```
#pragma include_alias (<stdio.h> , <C:\MyHeaders\stdio.h>)
#include <stdio.h>
```

This example will substitute the relative file `stdio.h` with a counterpart located according to the specified path.

See also

Include file search procedure, page 243.

inline

Syntax

```
#pragma inline[=forced|=never]
```

Parameters

No parameter	Has the same effect as the `inline` keyword.
`forced`	Disables the compiler's heuristics and forces inlining.
`never`	Disables the compiler's heuristics and makes sure that the function will not be inlined.

Description

Use `#pragma inline` to advise the compiler that the function defined immediately after the directive should be inlined according to C++ inline semantics.

Specifying `#pragma inline=forced` will always inline the defined function. If the compiler fails to inline the function for some reason, for example due to recursion, a warning message is emitted.

Inlining is normally performed only on the High optimization level. Specifying `#pragma inline=forced` will inline the function or result in an error due to recursion etc.

See also *Inlining functions*, page 85.

language

Syntax

```
#pragma language={extended|default|save|restore}
```

Parameters

`extended`	Enables the IAR Systems language extensions from the first use of the pragma directive and onward.
`default`	From the first use of the pragma directive and onward, restores the settings for the IAR Systems language extensions to whatever that was specified by compiler options.
`save|restore`	Saves and restores, respectively, the IAR Systems language extensions setting around a piece of source code. Each use of `save` must be followed by a matching `restore` in the same file without any intervening `#include` directive.

Description

Use this pragma directive to control the use of language extensions.

Example

At the top of a file that needs to be compiled with IAR Systems extensions enabled:

```
#pragma language=extended
/* The rest of the file. */
```

Around a particular part of the source code that needs to be compiled with IAR Systems extensions enabled, but where the state before the sequence cannot be assumed to be the same as that specified by the compiler options in use:

```
#pragma language=save
#pragma language=extended
/* Part of source code. */
#pragma language=restore
```

See also -*e*, page 267 and --*strict*, page 289.

location

Syntax

```
#pragma location={address|NAME}
```

Parameters

address	The absolute address of the global or static variable for which you want an absolute location.
NAME	A user-defined section name—cannot be a section name predefined for use by the compiler and linker.

Description

Use this pragma directive to specify the location—the absolute address—of the global or static variable whose declaration follows the pragma directive. Alternatively, the directive can take a string specifying a section for placing either a variable or a function whose declaration follows the pragma directive. Do not place variables that would normally be in different sections—for example, variables declared as `__no_init` and variables declared as `const`—in the same named section.

Example

```
#pragma location=0xFF2000
__no_init volatile char PORT1; /* PORT1 is located at address
                                  0xFF2000 */

#pragma segment="FLASH"
#pragma location="FLASH"
__no_init char PORT2; /* PORT2 is located in section FLASH */

/* A better way is to use a corresponding mechanism */
#define FLASH _Pragma("location=\"FLASH\"")
/* ... */
FLASH __no_init int i; /* i is placed in the FLASH section */
```

See also

Controlling data and function placement in memory, page 224 and *Declare and place your own sections*, page 110.

message

Syntax

```
#pragma message(message)
```

Parameters

message	The message that you want to direct to the standard output stream.

Description
Use this pragma directive to make the compiler print a message to the standard output stream when the file is compiled.

Example
```
#ifdef TESTING
#pragma message("Testing")
#endif
```

no_stack_protect

Syntax
```
#pragma no_stack_protect
```

Description
Use this pragma directive to disable stack protection for the defined function that follows.

This pragma directive only has effect if the compiler option `--stack_protection` has been used.

See also
Stack protection, page 87.

object_attribute

Syntax
```
#pragma object_attribute=object_attribute[ object_attribute...]
```

Parameters
For information about object attributes that can be used with this pragma directive, see *Object attributes*, page 344.

Description
Use this pragma directive to add one or more IAR-specific object attributes to the declaration or definition of a variable or function. Object attributes affect the actual variable or function and not its type. When you define a variable or function, the union of the object attributes from all declarations including the definition, is used.

Example
```
#pragma object_attribute=__no_init
char bar;
```

is equivalent to:

```
__no_init char bar;
```

See also
General syntax rules for extended keywords, page 341.

optimize

Syntax `#pragma optimize=[goal][level][disable]`

Parameters

goal Choose between:

`size`, optimizes for size

`balanced`, optimizes balanced between speed and size

`speed`, optimizes for speed.

`no_size_constraints`, optimizes for speed, but relaxes the normal restrictions for code size expansion.

level Specifies the level of optimization—choose between `none`, `low`, `medium`, or `high`.

disable Disables one or several optimizations (separated by spaces). Choose between:

`no_code_motion`, disables code motion

`no_cse`, disables common subexpression elimination

`no_inline`, disables function inlining

`no_relaxed_fp`, disables the language relaxation that optimizes floating-point expressions more aggressively

`no_tbaa`, disables type-based alias analysis

`no_unroll`, disables loop unrolling

Description

Use this pragma directive to decrease the optimization level, or to turn off some specific optimizations. This pragma directive only affects the function that follows immediately after the directive.

The parameters `size`, `balanced`, `speed`, and `no_size_constraints` only have effect on the `high` optimization level and only one of them can be used as it is not possible to optimize for speed and size at the same time. It is also not possible to use preprocessor macros embedded in this pragma directive. Any such macro will not be expanded by the preprocessor.

Note: If you use the `#pragma optimize` directive to specify an optimization level that is higher than the optimization level you specify using a compiler option, the pragma directive is ignored.

Example

```
#pragma optimize=speed
int SmallAndUsedOften()
{
  /* Do something here. */
}

#pragma optimize=size
int BigAndSeldomUsed()
{
  /* Do something here. */
}
```

See also

Fine-tuning enabled transformations, page 230.

pack

Syntax

```
#pragma pack(n)
#pragma pack()
#pragma pack({push|pop}[,name] [,n])
```

Parameters

n	Sets an optional structure alignment—one of: `1`, `2`, `4`, `8`, or `16`
Empty list	Restores the structure alignment to default
`push`	Sets a temporary structure alignment
`pop`	Restores the structure alignment from a temporarily pushed alignment
name	An optional pushed or popped alignment label

Description

Use this pragma directive to specify the maximum alignment of `struct` and `union` members.

The `#pragma pack` directive affects declarations of structures following the pragma directive to the next `#pragma pack` or the end of the compilation unit.

Note: This can result in significantly larger and slower code when accessing members of the structure.

See also

Structure types, page 335.

__printf_args

Syntax

```
#pragma __printf_args
```

Description

Use this pragma directive on a function with a printf-style format string. For any call to that function, the compiler verifies that the argument to each conversion specifier, for example `%d`, is syntactically correct.

You cannot use this pragma directive on functions that are members of an overload set with more than one member.

Example

```
#pragma __printf_args
int printf(char const *,...);

void PrintNumbers(unsigned short x)
{
  printf("%d", x);  /* Compiler checks that x is an integer */
}
```

public_equ

Syntax

`#pragma public_equ="`*`symbol`*`",`*`value`*

Parameters

symbol	The name of the assembler symbol to be defined (string).
value	The value of the defined assembler symbol (integer constant expression).

Description

Use this pragma directive to define a public assembler label and give it a value.

Example

```
#pragma public_equ="MY_SYMBOL",0x123456
```

See also

--*public_equ*, page 285.

required

Syntax

`#pragma required=`*`symbol`*

Parameters

symbol	Any statically linked function or variable.

Description

Use this pragma directive to ensure that a symbol which is needed by a second symbol is included in the linked output. The directive must be placed immediately before the second symbol.

Use the directive if the requirement for a symbol is not otherwise visible in the application, for example, if a variable is only referenced indirectly through the section it resides in.

Example

```
const char copyright[] = "Copyright by me";

#pragma required=copyright
int main()
{
  /* Do something here. */
}
```

Even if the copyright string is not used by the application, it will still be included by the linker and available in the output.

rtmodel

Syntax

`#pragma rtmodel="key","value"`

Parameters

"*key*"	A text string that specifies the runtime model attribute.
"*value*"	A text string that specifies the value of the runtime model attribute. Using the special value * is equivalent to not defining the attribute at all.

Description

Use this pragma directive to add a runtime model attribute to a module, which can be used by the linker to check consistency between modules.

This pragma directive is useful for enforcing consistency between modules. All modules that are linked together and define the same runtime attribute key must have the same value for the corresponding key, or the special value `*`. It can, however, be useful to state explicitly that the module can handle any runtime model.

A module can have several runtime model definitions.

Note: The predefined compiler runtime model attributes start with a double underscore. To avoid confusion, this style must not be used in the user-defined attributes.

Example

```
#pragma rtmodel="I2C","ENABLED"
```

The linker will generate an error if a module that contains this definition is linked with a module that does not have the corresponding runtime model attributes defined.

__scanf_args

Syntax

```
#pragma __scanf_args
```

Description

Use this pragma directive on a function with a scanf-style format string. For any call to that function, the compiler verifies that the argument to each conversion specifier, for example `%d`, is syntactically correct.

You cannot use this pragma directive on functions that are members of an overload set with more than one member.

Example

```
#pragma __scanf_args
int scanf(char const *,...);

int GetNumber()
{
  int nr;
  scanf("%d", &nr);  /* Compiler checks that
                        the argument is a
                        pointer to an integer */

  return nr;
}
```

section

Syntax

`#pragma section="`*`NAME`*`" [`*`__memoryattribute`*`]`

alias

`#pragma segment="`*`NAME`*`" [`*`__memoryattribute`*`]`

Parameters

`NAME`	The name of the section.
`__memoryattribute`	An optional memory attribute identifying the memory the section will be placed in; if not specified, default memory is used.

Description

Use this pragma directive to define a section name that can be used by the section operators `__section_begin`, `__section_end`, and `__section_size`. All section declarations for a specific section must have the same memory type attribute and alignment.

If an optional memory attribute is used, the return type of the section operators `__section_begin` and `__section_end` is:

`void __memoryattribute *.`

Note: To place variables or functions in a specific section, use the `#pragma location` directive or the `@` operator.

Example

```
#pragma section="MYBREL" __brel
```

See also

Dedicated section operators, page 190 and the chapter *Linking your application*.

stack_protect

Syntax

```
#pragma stack_protect
```

Description

Use this pragma directive to force stack protection for the defined function that follows.

See also

Stack protection, page 87.

STDC CX_LIMITED_RANGE

Syntax

```
#pragma STDC CX_LIMITED_RANGE {ON|OFF|DEFAULT}
```

Parameters

`ON`	Normal complex mathematic formulas can be used.
`OFF`	Normal complex mathematic formulas cannot be used.
`DEFAULT`	Sets the default behavior, that is `OFF`.

Description

Use this pragma directive to specify that the compiler can use the normal complex mathematic formulas for `*` (multiplication), `/` (division), and `abs`.

Note: This directive is required by Standard C. The directive is recognized but has no effect in the compiler.

STDC FENV_ACCESS

Syntax
```
#pragma STDC FENV_ACCESS {ON|OFF|DEFAULT}
```

Parameters

`ON`	Source code accesses the floating-point environment. **Note:** This argument is not supported by the compiler.
`OFF`	Source code does not access the floating-point environment.
`DEFAULT`	Sets the default behavior, that is `OFF`.

Description

Use this pragma directive to specify whether your source code accesses the floating-point environment or not.

Note: This directive is required by Standard C.

STDC FP_CONTRACT

Syntax
```
#pragma STDC FP_CONTRACT {ON|OFF|DEFAULT}
```

Parameters

`ON`	The compiler is allowed to contract floating-point expressions.
`OFF`	The compiler is not allowed to contract floating-point expressions. **Note:** This argument is not supported by the compiler.
`DEFAULT`	Sets the default behavior, that is `ON`.

Description

Use this pragma directive to specify whether the compiler is allowed to contract floating-point expressions or not. This directive is required by Standard C.

Example
```
#pragma STDC FP_CONTRACT ON
```

type_attribute

Syntax
```
#pragma type_attribute=type_attr[ type_attr...]
```

Parameters

For information about type attributes that can be used with this pragma directive, see *Type attributes*, page 341.

Description

Use this pragma directive to specify IAR-specific *type attributes*, which are not part of Standard C. Note however, that a given type attribute might not be applicable to all kind of objects.

This directive affects the declaration of the identifier, the next variable, or the next function that follows immediately after the pragma directive.

Example

In this example, an `int` object with the memory attribute `__brel` is defined:

```
#pragma type_attribute=__brel
int x;
```

This declaration, which uses extended keywords, is equivalent:

```
__brel int x;
```

See also

The chapter *Extended keywords*.

unroll

Syntax

```
#pragma unroll=n
```

Parameters

n	The number of loop bodies in the unrolled loop, a constant integer. `#pragma unroll = 1` will prevent the unrolling of a loop.

Description

Use this pragma directive to specify that the loop following immediately after the directive should be unrolled and that the unrolled loop should have *n* copies of the loop body. The pragma directive can only be placed immediately before a `for`, `do`, or `while` loop, whose number of iterations can be determined at compile time.

Normally, unrolling is most effective for relatively small loops. However, in some cases, unrolling larger loops can be beneficial if it exposes opportunities for further optimizations between the unrolled loop iterations, for example, common subexpression elimination or dead code elimination.

The `#pragma unroll` directive can be used to force a loop to be unrolled if the unrolling heuristics are not aggressive enough. The pragma directive can also be used to reduce the aggressiveness of the unrolling heuristics.

Example

```
#pragma unroll=4
for (i = 0; i < 64; ++i)
{
  foo(i * k, (i + 1) * k);
}
```

See also *Loop unrolling*, page 231

vector

Syntax

```
#pragma vector=vector1[, vector2, vector3, ...]
```

Parameters

vectorN	The vector number(s) of an interrupt or call table function.

Description

Use this pragma directive to specify the vector(s) of an interrupt or call table function whose declaration follows the pragma directive. Note that several vectors can be defined for each function.

Example

```
#pragma vector=0x14
__interrupt void my_handler(void);
```

weak

Syntax

```
#pragma weak symbol1[=symbol2]
```

Parameters

symbol1	A function or variable with external linkage.
symbol2	A defined function or variable.

Description

This pragma directive can be used in one of two ways:

- To make the definition of a function or variable with external linkage a weak definition. The `__weak` attribute can also be used for this purpose.
- To create a weak alias for another function or variable. You can make more than one alias for the same function or variable.

Example

To make the definition of `foo` a weak definition, write:

```
#pragma weak foo
```

To make `NMI_Handler` a weak alias for `Default_Handler`, write:

```
#pragma weak NMI_Handler=Default_Handler
```

If `NMI_Handler` is not defined elsewhere in the program, all references to `NMI_Handler` will refer to `Default_Handler`.

Intrinsic functions

- Summary of intrinsic functions
- Descriptions of intrinsic functions

Summary of intrinsic functions

The intrinsic functions provide direct access to low-level processor operations and can be very useful in, for example, time-critical routines. The intrinsic functions compile into inline code, either as a single instruction or as a short sequence of instructions.

To use intrinsic functions in an application, include the header file `intrinsics.h`.

Note that the intrinsic function names start with double underscores, for example:

`__disable_interrupt`

This table summarizes the intrinsic functions:

Intrinsic function	Description
`__BSH`	Inserts a `BSH` instruction
`__BSW`	Inserts a `BSW` instruction
`__CAXI`	Inserts a `CAXI` instruction
`__CEILF_DL`	Inserts a `CEILF.DL` instruction
`__CEILF_DUL`	Inserts a `CEILF.DUL` instruction
`__CEILF_DUW`	Inserts a `CEILF.DUW` instruction
`__CEILF_DW`	Inserts a `CEILF.DW` instruction
`__CEILF_SL`	Inserts a `CEILF.SL` instruction
`__CEILF_SUL`	Inserts a `CEILF.SUL` instruction
`__CEILF_SUW`	Inserts a `CEILF.SUW` instruction
`__CEILF_SW`	Inserts a `CEILF.SW` instruction
`__DBCP`	Inserts a `DBCP` instruction
`__DBHVTRAP`	Inserts a `DBHVTRAP` instruction
`__DBPUSH`	Pushes a register set to the debug interface
`__DBRET`	Inserts a `DBRET` instruction
`__DBTAG`	Generates a debug tag

Table 31: Intrinsic functions summary

Intrinsic function	Description
`__DBTRAP`	Inserts a `DBTRAP` instruction
`__disable_interrupt`	Disables interrupts
`__DST`	Inserts a `DST` instruction
`__enable_interrupt`	Enables interrupts
`__EST`	Inserts an `EST` instruction
`__FLOORF_DL`	Inserts a `FLOORF.DL` instruction
`__FLOORF_DUL`	Inserts a `FLOORF.DUL` instruction
`__FLOORF_DUW`	Inserts a `FLOORF.DUW` instruction
`__FLOORF_DW`	Inserts a `FLOORF.DW` instruction
`__FLOORF_SL`	Inserts a `FLOORF.SL` instruction
`__FLOORF_SUL`	Inserts a `FLOORF.SUL` instruction
`__FLOORF_SUW`	Inserts a `FLOORF.SUW` instruction
`__FLOORF_SW`	Inserts a `FLOORF.SW` instruction
`__get_interrupt_state`	Returns the interrupt state
`__halt`	Inserts a `HALT` instruction
`__HSW`	Inserts an `HSW` instruction
`__LDL`	Inserts an `LDL` instruction
`__LDSR`	Inserts an `LDSR` instruction
`__MAC`	Executes MAC operations on 32-bit signed data values and returns a 64-bit signed value
`__MACU`	Executes MAC operations on 32-bit unsigned data values and returns a 64-bit unsigned value
`__MADDF`	Inserts an `MADDF` instruction
`__MSUBF`	Inserts an `MSUBF` instruction
`__NMADDF`	Inserts an `NMADDF` instruction
`__NMSUBF`	Inserts an `NMSUBF` instruction
`__no_operation`	Inserts a `NOP` instruction
`__RECIPF_D`	Inserts a `RECIPF.D` instruction
`__RECIPF_S`	Inserts a `RECIPF.S` instruction
`__RMTRAP`	Inserts an `RMTRAP` instruction
`__ROUNDF_DL`	Inserts a `ROUNDF.DL` instruction
`__ROUNDF_DUL`	Inserts a `ROUNDF.DUL` instruction

Table 31: Intrinsic functions summary (Continued)

Intrinsic function	Description
__ROUNDF_DUW	Inserts a ROUNDF.DUW instruction
__ROUNDF_DW	Inserts a ROUNDF.DW instruction
__ROUNDF_SL	Inserts a ROUNDF.SL instruction
__ROUNDF_SUL	Inserts a ROUNDF.SUL instruction
__ROUNDF_SUW	Inserts a ROUNDF.SUW instruction
__ROUNDF_SW	Inserts a ROUNDF.SW instruction
__saturated_add	Inserts a SATADD instruction
__saturated_sub	Inserts a SATSUB instruction
__SCH0L	Inserts an SCH0L instruction
__SCH0R	Inserts an SCH0R instruction
__SCH1L	Inserts an SCH1L instruction
__SCH1R	Inserts an SCH1R instruction
__set_interrupt_state	Restores the interrupt state
__snooze	Inserts a SNOOZE instruction
__SQRTF_D	Inserts an SQRTF.D instruction
__SQRTF_S	Inserts an SQRTF.S instruction
__STC	Inserts an STC instruction
__STSR	Inserts an STSR instruction
__SYNCE	Inserts a SYNCE instruction
__SYNCI	Inserts a SYNCI instruction
__SYNCM	Inserts a SYNCM instruction
__SYNCP	Inserts a SYNCP instruction
__TLBAI	Inserts a TLBAI instruction
__TLBR	Inserts a TLBR instruction
__TLBS	Inserts a TLBS instruction
__TLBVI	Inserts a TLBVI instruction
__TLBW	Inserts a TLBW instruction
__TRNCF_DL	Inserts a TRNCF.DL instruction
__TRNCF_DUL	Inserts a TRNCF.DUL instruction
__TRNCF_DUW	Inserts a TRNCF.DUW instruction
__TRNCF_DW	Inserts a TRNCF.DW instruction
__TRNCF_SL	Inserts a TRNCF.SL instruction

Table 31: Intrinsic functions summary (Continued)

Intrinsic function	Description
`__TRNCF_SUL`	Inserts a `TRNCF.SUL` instruction
`__TRNCF_SUW`	Inserts a `TRNCF.SUW` instruction
`__TRNCF_SW`	Inserts a `TRNCF.SW` instruction
`__upper_mul64`	Returns the 32 most significant bits of a 64-bit multiplication of two 32-bit long values.

Table 31: Intrinsic functions summary (Continued)

Descriptions of intrinsic functions

This section gives reference information about each intrinsic function.

__BSH

Syntax

```
long __BSH(long);
```

Description

Inserts a `BSH` instruction.

__BSW

Syntax

```
long __BSW(long);
```

Description

Inserts a `BSW` instruction.

__CAXI

Syntax

```
int __caxi(int *, int, int);
```

Description

Inserts a `CAXI` instruction.

__CEILF_DL

Syntax

```
long long __CEILF_DL(double);
```

Description

Inserts a `CEILF.DL` instruction.

__CEILF_DUL

Syntax `unsigned long long __CEILF_DUL(double);`

Description Inserts a `CEILF.DUL` instruction.

__CEILF_DUW

Syntax `unsigned long __CEILF_DUW(double);`

Description Inserts a `CEILF.DUW` instruction.

__CEILF_DW

Syntax `long __CEILF_DW(double);`

Description Inserts a `CEIL.FDW` instruction.

__CEILF_SL

Syntax `long long __CEILF_SL(float);`

Description Inserts a `CEILF.SL` instruction.

__CEILF_SUL

Syntax `unsigned long long __CEILF_SUL(float);`

Description Inserts a `CEILF.SUL` instruction.

__CEILF_SUW

Syntax `unsigned long __CEILF_SUW(float);`

Description Inserts a `CEILF.SUW` instruction.

__CEILF_SW

Syntax
```
long __CEILF_SW(float);
```

Description

Inserts a `CEILF.SW` instruction.

__DBCP

Syntax
```
void __DBCP(void);
```

Description

Inserts a `DBCP` instruction.

__DBHVTRAP

Syntax
```
void __DBHVTRAP(void);
```

Description

Inserts a `DBHVTRAP` instruction.

__DBPUSH

Syntax
```
void __DBPUSH(long first, long last);
```

Description

Pushes the register set `R`*`first`*–`R`*`last`* to the debug interface. Both *`first`* and *`last`* must be in the range 0–31 (inclusive).

__DBRET

Syntax
```
void __DBRET(void);
```

Description

Inserts a `DBRET` instruction.

__DBTAG

Syntax
```
void __DBTAG(long num);
```

Description

Generates the debug tag *`num`* (immediate value 0–1023).

__DBTRAP

Syntax `void __DBTRAP(void);`

Description Inserts a `DBTRAP` instruction.

__disable_interrupt

Syntax `void __disable_interrupt(void);`

Description Disables interrupts by inserting the `DI` instruction.

__DST

Syntax `void __DST(void);`

Description Inserts a `DST` instruction.

__enable_interrupt

Syntax `void __enable_interrupt(void);`

Description Enables interrupts by inserting the `EI` instruction.

__EST

Syntax `void __EST(void);`

Description Inserts an `EST` instruction.

__FLOORF_DL

Syntax `long long __FLOORF_DL(double);`

Description Inserts a `FLOORF.DL` instruction.

__FLOORF_DUL

Syntax `unsigned long long __FLOORF_DUL(double);`

Description Inserts a `FLOORF.DUL` instruction.

__FLOORF_DUW

Syntax `unsigned long __FLOORF_DUW(double);`

Description Inserts a `FLOORF.DUW` instruction.

__FLOORF_DW

Syntax `long __FLOORF_DW(double);`

Description Inserts a `FLOORF.DW` instruction.

__FLOORF_SL

Syntax `long long __FLOORF_SL(float);`

Description Inserts a `FLOORF.SL` instruction.

__FLOORF_SUL

Syntax `unsigned long long __FLOORF_SUL(float);`

Description Inserts a `FLOORF.SUL` instruction.

__FLOORF_SUW

Syntax `unsigned long __FLOORF_SUW(float);`

Description Inserts a `FLOORF.SUW` instruction.

__FLOORF_SW

Syntax

```
long __FLOORF_SW(float);
```

Description

Inserts a `FLOORF.SW` instruction.

__get_interrupt_state

Syntax

```
__istate_t __get_interrupt_state(void);
```

Description

Returns the global interrupt state. The return value can be used as an argument to the `__set_interrupt_state` intrinsic function, which will restore the interrupt state.

Example

```
#include "intrinsics.h"

void CriticalFn()
{
  __istate_t s = __get_interrupt_state();
  __disable_interrupt();

  /* Do something here. */

  __set_interrupt_state(s);
}
```

The advantage of using this sequence of code compared to using `__disable_interrupt` and `__enable_interrupt` is that the code in this example will not enable any interrupts disabled before the call of `__get_interrupt_state`.

__halt

Syntax

```
void __halt(void);
```

Description

Inserts a `HALT` instruction.

__HSW

Syntax

```
long __HSW(long);
```

Description

Inserts an `HSW` instruction.

__LDL

Syntax

```
long __LDL(long *);
```

Description

Inserts an `LDL` instruction.

__LDSR

Syntax

```
void __LDSR(int reg, int selID, long val);
```

Parameters

reg	The number of the system register that the function will write to.
selID	The group number of the system register that the function will write to.
val	The value to write to the register.

Description

Writes a specific value to a system register.

__MAC

Syntax

```
signed long long __MAC(signed long val1, signed long val2,
signed long long accumulator);
```

Description

Executes multiply and accumulate (MAC) operations on the 32-bit signed data values *val1* and *val2* and returns the result as a 64-bit signed data value.

__MACU

Syntax

```
unsigned long long __MACU(unsigned long val1, unsigned long val2,
unsigned long long accumulator);
```

Description

Executes multiply and accumulate (MAC) operations on the 32-bit unsigned data values *val1* and *val2* and returns the result as a 64-bit unsigned data value.

__MADDF

Syntax

```
float __MADDF(float, float, float);
```

Description

Inserts an `MADDF` instruction.

__MSUBF

Syntax `float __MSUBF(float, float, float);`

Description Inserts an `MSUBF` instruction.

__NMADDF

Syntax `float __NMADDF(float, float, float);`

Description Inserts an `NMADDF` instruction.

__NMSUBF

Syntax `float __NMSUBF(float, float, float);`

Description Inserts an `NMSUBF` instruction.

__no_operation

Syntax `void __no_operation(void);`

Description Inserts a `NOP` instruction.

__RECIPF_D

Syntax `double __RECIPF_D(double);`

Description Inserts a `RECIPF.D` instruction.

__RECIPF_S

Syntax `float __RECIPF_S(float);`

Description Inserts a `RECIPF.S` instruction.

__RMTRAP

Syntax
```
void __RMTRAP(void);
```

Description

Inserts an `RMTRAP` instruction.

__ROUNDF_DL

Syntax
```
long long __ROUNDF_DL(double);
```

Description

Inserts a `ROUNDF.DL` instruction.

__ROUNDF_DUL

Syntax
```
unsigned long long __ROUNDF_DUL(double);
```

Description

Inserts a `ROUNDF.DUL` instruction.

__ROUNDF_DUW

Syntax
```
unsigned long __ROUNDF_DUW(double);
```

Description

Inserts a `ROUNDF.DUW` instruction.

__ROUNDF_DW

Syntax
```
long __ROUNDF_DW(double);
```

Description

Inserts a `ROUNDF.DW` instruction.

__ROUNDF_SL

Syntax
```
long long __ROUNDF_SL(float);
```

Description

Inserts a `ROUNDF.SL` instruction.

__ROUNDF_SUL

Syntax `unsigned long long __ROUNDF_SUL(float);`

Description Inserts a `ROUNDF.SUL` instruction.

__ROUNDF_SUW

Syntax `unsigned long __ROUNDF_SUW(float);`

Description Inserts a `ROUNDF.SUW` instruction.

__ROUNDF_SW

Syntax `long __ROUNDF_SW(float);`

Description Inserts a `ROUNDF.SW` instruction.

__RSQRTF_D

Syntax `double __RSQRTF_D(double);`

Description Inserts an `RSQRTF.D` instruction.

__RSQRTF_S

Syntax `float __RSQRTF_S(float);`

Description Inserts an `RSQRTF.S` instruction.

__saturated_add

Syntax `long __saturated_add(long long);`

Description Inserts a `SATADD` instruction.

__saturated_sub

Syntax `long __saturated_sub(long long);`

Description Inserts a `SATSUB` instruction.

__SCH0L

Syntax `long __SCH0L(long);`

Description Inserts an `SCH0L` instruction.

__SCH0R

Syntax `long __SCH0R(long);`

Description Inserts an `SCH0R` instruction.

__SCH1L

Syntax `long __SCH1L(long);`

Description Inserts an `SCH1L` instruction.

__SCH1R

Syntax `long __SCH1R(long);`

Description Inserts an `SCH1R` instruction.

__set_interrupt_state

Syntax `void __set_interrupt_state(__istate_t);`

Description Restores the interrupt state to a value previously returned by the `__get_interrupt_state` function.

For information about the `__istate_t` type, see *__get_interrupt_state*, page 393.

__snooze

Syntax `void __snooze(void);`

Description Inserts a `SNOOZE` instruction.

__SQRTF_D

Syntax `double __SQRTF_D(double);`

Description Inserts an `SQRTF.D` instruction.

__SQRTF_S

Syntax `float __SQRTF_S(float);`

Description Inserts an `SQRTF.S` instruction.

__STC

Syntax `long __STC(long *, long);`

Description Inserts an `STC` instruction.

__STSR

Syntax `long __STSR(int reg, int selID);`

Parameters

reg	The number of the system register whose value the function returns.
selID	The group number of the system register whose value the function returns.

Description Returns the value of a system register.

__SYNCE

Syntax `void __SYNCE(void);`

Description Inserts a `SYNCE` instruction.

__SYNCI

Syntax `void __SYNCI(void);`

Description Inserts a `SYNCI` instruction.

__SYNCM

Syntax `void __SYNCM(void);`

Description Inserts a `SYNCM` instruction.

__SYNCP

Syntax `void __SYNCP(void);`

Description Inserts a `SYNCP` instruction.

__TLBAI

Syntax `void __TLBAI(void);`

Description Inserts a `TLBAI` instruction.

__TLBR

Syntax `void __TLBR(void);`

Description Inserts a `TLBR` instruction.

__TLBS

Syntax `void __TLBS(void);`

Description Inserts a `TLBS` instruction.

__TLBVI

Syntax `void __TLBVI(void);`

Description Inserts a `TLBVI` instruction.

__TLBW

Syntax `void __TLBW(void);`

Description Inserts a `TLBW` instruction.

__TRNCF_DL

Syntax `long long __TRNCF_DL(double);`

Description Inserts a `TRNCF.DL` instruction.

__TRNCF_DUL

Syntax `unsigned long long __TRNCF_DUL(double);`

Description Inserts a `TRNCF.DUL` instruction.

__TRNCF_DUW

Syntax `unsigned long __TRNCF_DUW(double);`

Description Inserts a `TRNCF.DUW` instruction.

__TRNCF_DW

Syntax `long __TRNCF_DW(double);`

Description Inserts a `TRNCF.DW` instruction.

__TRNCF_SL

Syntax `long long __TRNCF_SL(float);`

Description Inserts a `TRNCF.SL` instruction.

__TRNCF_SUL

Syntax `unsigned long long __TRNCF_SUL(float);`

Description Inserts a `TRNCF.SUL` instruction.

__TRNCF_SUW

Syntax `unsigned long __TRNCF_SUW(float);`

Description Inserts a `TRNCF.SUW` instruction.

__TRNCF_SW

Syntax `long __TRNCF_SW(float);`

Description Inserts a `TRNCF.SW` instruction.

__upper_mul64

Syntax `long __upper_mul64(long, long);`

Description Returns the 32 most significant bits of a 64-bit multiplication of two 32-bit long values.

The preprocessor

- Overview of the preprocessor
- Description of predefined preprocessor symbols
- Descriptions of miscellaneous preprocessor extensions

Overview of the preprocessor

The preprocessor of the IAR C/C++ Compiler for RH850 adheres to Standard C. The compiler also makes these preprocessor-related features available to you:

- Predefined preprocessor symbols

  These symbols allow you to inspect the compile-time environment, for example, the time and date of compilation. For more information, see *Description of predefined preprocessor symbols*, page 404.
- User-defined preprocessor symbols defined using a compiler option

  In addition to defining your own preprocessor symbols using the `#define` directive, you can also use the option `-D`, see *-D*, page 260.
- Preprocessor extensions

  There are several preprocessor extensions, for example, many pragma directives. For more information, see the chapter *Pragma directives*. For information about the other extensions related to the preprocessor, see *Descriptions of miscellaneous preprocessor extensions*, page 409.
- Preprocessor output

  Use the option `--preprocess` to direct preprocessor output to a named file, see *--preprocess*, page 285.

To specify a path for an include file, use forward slashes:

```
#include "mydirectory/myfile"
```

In source code, use forward slashes:

```
file = fopen("mydirectory/myfile","rt");
```

Note: Backslashes can also be used—use one in include file paths and two in source code strings.

Description of predefined preprocessor symbols

This section lists and describes the preprocessor symbols.

Note: To list the predefined preprocessor symbols, use the compiler option `--predef_macros`. See --*predef_macros*, page 284.

__BASE_FILE__

Description

A string that identifies the name of the base source file (that is, not the header file), being compiled.

See also

__FILE__, page 405, and --*no_path_in_file_macros*, page 279.

__BUILD_NUMBER__

Description

A unique integer that identifies the build number of the compiler currently in use. The build number does not necessarily increase with a compiler that is released later.

__CORE__

Description

An integer that identifies the chip core in use. The value reflects the setting of the `--core` option and is defined to `__CORE_G3K__`, `__CORE_G3KH__`, `__CORE_G3M__`, `__CORE_G3MH__`, or `__CORE_G4MH__`. This symbolic name can be used when testing the `__CORE__` symbol.

__COUNTER__

Description

A macro that expands to a new integer each time it is expanded, starting at zero (0) and counting up.

__cplusplus

Description

An integer which is defined when the compiler runs in any of the C++ modes, otherwise it is undefined. When defined, its value is `201402L`. This symbol can be used with `#ifdef` to detect whether the compiler accepts C++ code. It is particularly useful when creating header files that are to be shared by C and C++ code.

This symbol is required by Standard C.

__DATA_MODEL__

Description

An integer that identifies the data model in use. The value reflects the setting of the `--data_model` option and is defined to `__DATA_MODEL_TINY__`, `__DATA_MODEL_SMALL__`, `__DATA_MODEL_MEDIUM__`, or `__DATA_MODEL_LARGE__`. These symbolic names can be used when testing the `__DATA_MODEL__` symbol.

__DATE__

Description

A string that identifies the date of compilation, which is returned in the form "`Mmm dd yyyy`", for example, "`Oct 30 2018`".

This symbol is required by Standard C.

__DOUBLE__

Description

An integer that identifies the size of the data type `double`. The symbol reflects the `--double` option and is defined to 32 or 64.

__EXCEPTIONS

Description

A symbol that is defined when exceptions are supported in C++.

__FILE__

Description

A string that identifies the name of the file being compiled, which can be both the base source file and any included header file.

This symbol is required by Standard C.

See also

__BASE_FILE__, page 404, and --*no_path_in_file_macros*, page 279.

__FPU__

Description

Specifies the selected floating-point unit. The symbol reflects the `--fpu` option and is defined to `__FPU_NONE__`, `__FPU_SINGLE__`, or `__FPU_DOUBLE__`.

__func__

Description

A predefined string identifier that is initialized with the name of the function in which the symbol is used. This is useful for assertions and other trace utilities. The symbol requires that language extensions are enabled.

This symbol is required by Standard C.

See also

-*e*, page 267 and *__PRETTY_FUNCTION__*, page 407.

__FUNCTION__

Description

A predefined string identifier that is initialized with the name of the function in which the symbol is used. This is useful for assertions and other trace utilities. The symbol requires that language extensions are enabled.

See also

-*e*, page 267 and *__PRETTY_FUNCTION__*, page 407.

__IAR_SYSTEMS_ICC__

Description

An integer that identifies the IAR compiler platform. The current value is 9—the number could be higher in a future version of the product. This symbol can be tested with `#ifdef` to detect whether the code was compiled by a compiler from IAR Systems.

__ICCRH850__

Description

An integer that is set to `1` when the code is compiled with the IAR C/C++ Compiler for RH850.

__LINE__

Description

An integer that identifies the current source line number of the file being compiled, which can be both the base source file and any included header file.

This symbol is required by Standard C.

__LITTLE_ENDIAN__

Description

An integer that reflects the byte order and is defined to `1` (little-endian).

__PRETTY_FUNCTION__

Description

A predefined string identifier that is initialized with the function name, including parameter types and return type, of the function in which the symbol is used, for example, `"void func(char)"`. This symbol is useful for assertions and other trace utilities. The symbol requires that language extensions are enabled.

See also

-e, page 267 and *__func__*, page 406.

__RTTI__

Description

A symbol that is defined when runtime type information (RTTI) is supported in C++.

__SADDR_ACTIVE__

Description

An integer that is defined to `1` when saddr support is enabled.

__STDC__

Description

An integer that is set to `1`, which means the compiler adheres to Standard C. This symbol can be tested with `#ifdef` to detect whether the compiler in use adheres to Standard C.*

This symbol is required by Standard C.

__STDC_LIB_EXT1__

Description

An integer that is set to `201112L` and that signals that Annex K, *Bounds-checking interfaces*, of the C standard is supported.

See also

__STDC_WANT_LIB_EXT1__, page 409.

__STDC_NO_ATOMICS__

Description

Set to `1` if the compiler does not support atomic types nor `stdatomic.h`.

__STDC_NO_THREADS__

Description

Set to `1` to indicate that the implementation does not support threads.

__STDC_NO_VLA__

Description

Set to `1` to indicate that C variable length arrays, VLAs, are not enabled.

See also

--vla, page 292.

__STDC_UTF16__

Description

Set to `1` to indicate that the values of type `char16_t` are UTF-16 encoded.

__STDC_UTF32__

Description

Set to `1` to indicate that the values of type `char32_t` are UTF-32 encoded.

__STDC_VERSION__

Description

An integer that identifies the version of the C standard in use. The symbol expands to `201710L`, unless the `--c89` compiler option is used, in which case the symbol expands to `199409L`.

This symbol is required by Standard C.

__SUBVERSION__

Description

An integer that identifies the subversion number of the compiler version number, for example 3 in 1.2.3.4.

__TIME__

Description

A string that identifies the time of compilation in the form `"hh:mm:ss"`.

This symbol is required by Standard C.

__TIMESTAMP__

Description

A string constant that identifies the date and time of the last modification of the current source file. The format of the string is the same as that used by the `asctime` standard function (in other words, `"Tue Sep 16 13:03:52 2014"`).

__VER__

Description

An integer that identifies the version number of the IAR compiler in use. The value of the number is calculated in this way: `(100 * the major version number + the minor version number)`. For example, for compiler version 3.34, 3 is the major version number and 34 is the minor version number. Hence, the value of `__VER__` is 334.

Descriptions of miscellaneous preprocessor extensions

This section gives reference information about the preprocessor extensions that are available in addition to the predefined symbols, pragma directives, and Standard C directives.

NDEBUG

Description

This preprocessor symbol determines whether any assert macros you have written in your application shall be included or not in the built application.

If this symbol is not defined, all assert macros are evaluated. If the symbol is defined, all assert macros are excluded from the compilation. In other words, if the symbol is:

- **defined**, the assert code will *not* be included
- **not defined**, the assert code will be included

This means that if you write any assert code and build your application, you should define this symbol to exclude the assert code from the final application.

Note: The assert macro is defined in the `assert.h` standard include file.

In the IDE, the `NDEBUG` symbol is automatically defined if you build your application in the Release build configuration.

See also

__iar_ReportAssert, page 151.

__STDC_WANT_LIB_EXT1__

Description

If this symbol is defined to 1 prior to any inclusions of system header files, it will enable the use of functions from Annex K, *Bounds-checking interfaces*, of the C standard.

See also

Bounds checking functionality, page 134 and *C bounds-checking interface*, page 420.

#warning message

Syntax

```
#warning message
```

where *message* can be any string.

Description

Use this preprocessor directive to produce messages. Typically, this is useful for assertions and other trace utilities, similar to the way the Standard C `#error` directive is used. This directive is not recognized when the `--strict` compiler option is used.

C/C++ standard library functions

- C/C++ standard library overview
- DLIB runtime environment—implementation details

For detailed reference information about the library functions, see the online help system.

C/C++ standard library overview

The IAR DLIB Runtime Environment is a complete implementation of the C/C++ standard library, compliant with Standard C and C++. This library also supports floating-point numbers in IEC 60559 format, and it can be configured to include different levels of support for locale, file descriptors, multibyte characters, etc.

For more information about customization, see the chapter *The DLIB runtime environment*.

For detailed information about the library functions, see the online documentation supplied with the product. There is also keyword reference information for the DLIB library functions. To obtain reference information for a function, select the function name in the editor window and press F1.

For more information about library functions, see the chapter *Implementation-defined behavior for Standard C*.

HEADER FILES

Your application program gains access to library definitions through header files, which it incorporates using the `#include` directive. The definitions are divided into several different header files, each covering a particular functional area, letting you include just those that are required.

It is essential to include the appropriate header file before making any reference to its definitions. Failure to do so can cause the call to fail during execution, or generate error or warning messages at compile time or link time.

LIBRARY OBJECT FILES

Most of the library definitions can be used without modification, that is, directly from the library object files that are supplied with the product. For information about how to set up a runtime library, see *Setting up the runtime environment*, page 127. The linker will include only those routines that are required—directly or indirectly—by your application.

For information about how you can override library modules with your own versions, see *Overriding library modules*, page 131.

ALTERNATIVE MORE ACCURATE LIBRARY FUNCTIONS

The default implementation of `cos`, `sin`, `tan`, and `pow` is designed to be fast and small. As an alternative, there are versions designed to provide better accuracy. They are named `__iar_`*`xxx`*`_accuratef` for `float` variants of the functions and `__iar_`*`xxx`*`_accuratel` for `long double` variants of the functions, and where *xxx* is `cos`, `sin`, etc.

To use these more accurate versions, use the `--accurate_math` linker option.

REENTRANCY

A function that can be simultaneously invoked in the main application and in any number of interrupts is reentrant. A library function that uses statically allocated data is therefore not reentrant.

Most parts of the DLIB runtime environment are reentrant, but the following functions and parts are not reentrant because they need static data:

- Heap functions—`malloc`, `free`, `realloc`, `calloc`, etc. and the C++ operators `new` and `delete`
- Locale functions—`localeconv`, `setlocale`
- Multibyte functions—`mblen`, `mbrlen`, `mbrtowc`, `mbsrtowc`, `mbtowc`, `wcrtomb`, `wcsrtomb`, `wctomb`
- Rand functions—`rand`, `srand`
- Time functions—`asctime`, `localtime`, `gmtime`, `mktime`
- The miscellaneous functions `atexit`, `perror`, `strerror`, `strtok`
- Functions that use files or the heap in some way. This includes `scanf`, `sscanf`, `getchar`, `getwchar`, `putchar`, and `putwchar`. In addition, if you are using the options `--enable_multibyte` and `--dlib_config=Full`, the `printf` and `sprintf` functions (or any variants) can also use the heap.

Functions that can set `errno` are not reentrant, because an `errno` value resulting from one of these functions can be destroyed by a subsequent use of the function before it is read. This applies to math and string conversion functions, among others.

Remedies for this are:

- Do not use non-reentrant functions in interrupt service routines
- Guard calls to a non-reentrant function by a mutex, or a secure region, etc.

THE LONGJMP FUNCTION

A `longjmp` is in effect a jump to a previously defined `setjmp`. Any variable length arrays or C++ objects residing on the stack during stack unwinding will not be destroyed. This can lead to resource leaks or incorrect application behavior.

DLIB runtime environment—implementation details

These topics are covered:

BRIEFLY ABOUT THE DLIB RUNTIME ENVIRONMENT

The DLIB runtime environment provides most of the important C and C++ standard library definitions that apply to embedded systems. These are of the following types:

- Adherence to a free-standing implementation of Standard C. The library supports most of the hosted functionality, but you must implement some of its base functionality. For more information, see the chapter *Implementation-defined behavior for Standard C*.
- Standard C library definitions, for user programs.
- C++ library definitions, for user programs.
- `CSTARTUP`, the module containing the start-up code, see the chapter *The DLIB runtime environment*.

- Runtime support libraries, for example, low-level floating-point routines.
- Intrinsic functions, allowing low-level use of RH850 features. For more information, see the chapter *Intrinsic functions*.

In addition, the DLIB runtime environment includes some added C functionality, see *Added C functionality*, page 419.

C HEADER FILES

This section lists the C header files specific to the DLIB runtime environment. Header files may additionally contain target-specific definitions, which are documented in the chapter *Using C*.

This table lists the C header files:

Header file	Usage
`assert.h`	Enforcing assertions when functions execute
`complex.h`	Computing common complex mathematical functions
`ctype.h`	Classifying characters
`errno.h`	Testing error codes reported by library functions
`fenv.h`	Floating-point exception flags
`float.h`	Testing floating-point type properties
`inttypes.h`	Defining formatters for all types defined in `stdint.h`
`iso646.h`	Alternative spellings
`limits.h`	Testing integer type properties
`locale.h`	Adapting to different cultural conventions
`math.h`	Computing common mathematical functions
`setjmp.h`	Executing non-local goto statements
`signal.h`	Controlling various exceptional conditions
`stdalign.h`	Handling alignment on data objects
`stdarg.h`	Accessing a varying number of arguments
`stdatomic.h`	Adding support for atomic operations. This functionality is not supported.
`stdbool.h`	Adds support for the `bool` data type in C.
`stddef.h`	Defining several useful types and macros
`stdint.h`	Providing integer characteristics
`stdio.h`	Performing input and output
`stdlib.h`	Performing a variety of operations

Table 32: Traditional Standard C header files—DLIB

Header file	Usage
`stdnoreturn.h`	Adding support for non-returning functions
`string.h`	Manipulating several kinds of strings
`tgmath.h`	Type-generic mathematical functions
`threads.h`	Adding support for multiple threads of execution This functionality is not supported.
`time.h`	Converting between various time and date formats
`uchar.h`	Unicode functionality
`wchar.h`	Support for wide characters
`wctype.h`	Classifying wide characters

Table 32: Traditional Standard C header files—DLIB (Continued)

C++ HEADER FILES

This section lists the C++ header files:

- The C++ library header files

  The header files that constitute the Standard C++ library.
- The C++ C header files

  The C++ header files that provide the resources from the C library.

The C++ library header files

This table lists the header files that can be used in C++:

Header file	Usage
`algorithm`	Defines several common operations on containers and other sequences
`array`	Adding support for the array sequencer container
`atomic`	Adding support for atomic operations This functionality is not supported.
`bitset`	Defining a container with fixed-sized sequences of bits
`chrono`	Adding support for time utilities
`codecvt`	Adding support for conversions between encodings
`complex`	Defining a class that supports complex arithmetic
`condition_variable`	Adding support for thread condition variables. This functionality is not supported.
`deque`	A deque sequence container

Table 33: C++ header files

Header file	Usage
exception	Defining several functions that control exception handling
forward_list	Adding support for the forward list sequence container
fstream	Defining several I/O stream classes that manipulate external files
functional	Defines several function objects
future	Adding support for passing function information between threads This functionality is not supported.
hash_map	A map associative container, based on a hash algorithm
hash_set	A set associative container, based on a hash algorithm
initializer_list	Adding support for the initializer_list class
iomanip	Declaring several I/O stream manipulators that take an argument
ios	Defining the class that serves as the base for many I/O streams classes
iosfwd	Declaring several I/O stream classes before they are necessarily defined
iostream	Declaring the I/O stream objects that manipulate the standard streams
istream	Defining the class that performs extractions
iterator	Defines common iterators, and operations on iterators
limits	Defining numerical values
list	A doubly-linked list sequence container
locale	Adapting to different cultural conventions
map	A map associative container
memory	Defines facilities for managing memory
mutex	Adding support for the data race protection object mutex. This functionality is not supported.
new	Declaring several functions that allocate and free storage
numeric	Performs generalized numeric operations on sequences
ostream	Defining the class that performs insertions
queue	A queue sequence container
random	Adding support for random numbers
ratio	Adding support for compile-time rational arithmetic
regex	Adding support for regular expressions

Table 33: C++ header files (Continued)

Header file	Usage
`scoped_allocator`	Adding support for the memory resource `scoped_allocator_adaptor`
`set`	A set associative container
`shared_mutex`	Adding support for the data race protection object `shared_mutex`. This functionality is not supported.
`slist`	A singly-linked list sequence container
`sstream`	Defining several I/O stream classes that manipulate string containers
`stack`	A stack sequence container
`stdexcept`	Defining several classes useful for reporting exceptions
`streambuf`	Defining classes that buffer I/O stream operations
`string`	Defining a class that implements a string container
`strstream`	Defining several I/O stream classes that manipulate in-memory character sequences
`system_error`	Adding support for global error reporting
`thread`	Adding support for multiple threads of execution. This functionality is not supported.
`tuple`	Adding support for the `tuple` class
`typeinfo`	Defining type information support
`typeindex`	Adding support for type indexes
`typetraits`	Adding support for traits on types
`unordered_map`	Adding support for the unordered map associative container
`unordered_set`	Adding support for the unordered set associative container
`utility`	Defines several utility components
`valarray`	Defining varying length array container
`vector`	A vector sequence container

Table 33: C++ header files (Continued)

Using Standard C libraries in C++

The C++ library works in conjunction with some of the header files from the Standard C library, sometimes with small alterations. The header files come in two forms—new and traditional—for example, `cassert` and `assert.h`. The former puts all declared symbols in the global and `std` namespace, whereas the latter puts them in the global namespace only.

This table shows the new header files:

Header file	Usage
cassert	Enforcing assertions when functions execute
ccomplex	Computing common complex mathematical functions
cctype	Classifying characters
cerrno	Testing error codes reported by library functions
cfenv	Floating-point exception flags
cfloat	Testing floating-point type properties
cinttypes	Defining formatters for all types defined in `stdint.h`
ciso646	Alternative spellings
climits	Testing integer type properties
clocale	Adapting to different cultural conventions
cmath	Computing common mathematical functions
csetjmp	Executing non-local goto statements
csignal	Controlling various exceptional conditions
cstdalign	Handling alignment on data objects
cstdarg	Accessing a varying number of arguments
cstdatomic	Adding support for atomic operations
cstdbool	Adds support for the `bool` data type in C.
cstddef	Defining several useful types and macros
cstdint	Providing integer characteristics
cstdio	Performing input and output
cstdlib	Performing a variety of operations
cstdnoreturn	Adding support for non-returning functions
cstring	Manipulating several kinds of strings
ctgmath	Type-generic mathematical functions
cthreads	Adding support for multiple threads of execution. This functionality is not supported.
ctime	Converting between various time and date formats
cuchar	Unicode functionality
cwchar	Support for wide characters
cwctype	Classifying wide characters

Table 34: New Standard C header files—DLIB

LIBRARY FUNCTIONS AS INTRINSIC FUNCTIONS

Certain C library functions will under some circumstances be handled as intrinsic functions and will generate inline code instead of an ordinary function call, for example, `memcpy`, `memset`, and `strcat`.

NOT SUPPORTED C/C++ FUNCTIONALITY

The following files have contents that are not supported by the IAR C/C++ Compiler:

- `stdatomic.h`, `atomic`
- `threads.h`, `condition_variable`, `future`, `mutex`, `shared_mutex`, `thread`, `cthreads`
- `exception`, `stdexcept`, `typeinfo`

Some library functions will have the same address. This occurs, most notably, when the library function parameters differ in type but not in size, as for example, `cos(double)` and `cosl(long double)`.

The IAR C/C++ compiler does not support threads as described in the C11 and C++14 standards. However, using `DLib_Threads.h` and an RTOS, you can build an application with thread support. For more information, see *Managing a multithreaded environment*, page 158.

ATOMIC OPERATIONS

Atomic operations using the files `stdatomic.h` and `atomic` are not available in the IAR C/C++ Compiler for RH850. The predefined preprocessor symbol `__STDC_NO_ATOMICS__` is always defined to `1`. This is true both in C and C++.

ADDED C FUNCTIONALITY

The DLIB runtime environment includes some added C functionality:

- C bounds-checking interface
- `DLib_Threads.h`
- `fenv.h`
- `LowLevelIOInterface.h`
- `stdio.h`
- `stdlib.h`
- `string.h`
- `time.h (time32.h, time64.h)`

C bounds-checking interface

The C library supports Annex K (*Bounds-checking interfaces*) of the C standard. It adds symbols, types, and functions in the header files `errno.h`, `stddef.h`, `stdint.h`, `stdio.h`, `stdlib.h`, `string.h`, `time.h` (`time32.h`, `time64.h`), and `wchar.h`.

To enable the interface, define the preprocessor extension `__STDC_WANT_LIB_EXT1__` to 1 prior to including any system header file. See *__STDC_WANT_LIB_EXT1__*, page 409.

As an added benefit, the compiler will issue warning messages for the use of unsafe functions for which the interface has a safer version. For example, using `strcpy` instead of the safer `strcpy_s` will make the compiler issue a warning message.

DLib_Threads.h

The `DLib_Threads.h` header file contains support for locks and thread-local storage (TLS) variables. This is useful for implementing thread support. For more information, see the header file.

fenv.h

In `fenv.h`, trap handling support for floating-point numbers is defined with the functions `fegettrapenable` and `fegettrapdisable`.

iar_dlmalloc.h

The `iar_dlmalloc.h` header file contains support for the advanced (`dlmalloc`) heap handler. For more information, see *Heap considerations*, page 204.

LowLevelIOInterface.h

The header file `LowLevelInterface.h` contains declarations for the low-level I/O functions used by DLIB. See *The DLIB low-level I/O interface*, page 147.

stdio.h

These functions provide additional I/O functionality:

`fdopen`	Opens a file based on a low-level file descriptor.
`fileno`	Gets the low-level file descriptor from the file descriptor (`FILE*`).
`__gets`	Corresponds to `fgets` on `stdin`.
`getw`	Gets a `wchar_t` character from `stdin`.

`putw`	Puts a `wchar_t` character to `stdout`.
`__ungetchar`	Corresponds to `ungetc` on `stdout`.
`__write_array`	Corresponds to `fwrite` on `stdout`.

string.h

These are the additional functions defined in `string.h`:

`strdup`	Duplicates a string on the heap.
`strcasecmp`	Compares strings case-insensitive.
`strncasecmp`	Compares strings case-insensitive and bounded.
`strnlen`	Bounded string length.

time.h

There are two interfaces for using `time_t` and the associated functions `time`, `ctime`, `difftime`, `gmtime`, `localtime`, and `mktime`:

- The 32-bit interface supports years from 1900 up to 2035 and uses a 32-bit integer for `time_t`. The type and function have names like `__time32_t`, `__time32`, etc. This variant is mainly available for backwards compatibility.
- The 64-bit interface supports years from -9999 up to 9999 and uses a signed `long long` for `time_t`. The type and function have names like `__time64_t`, `__time64`, etc.

The interfaces are defined in three header files:

- `time32.h` defines `__time32_t`, `time_t`, `__time32`, `time`, and associated functions.
- `time64.h` defines `__time64_t`, `time_t`, `__time64`, `time`, and associated functions.
- `time.h` includes `time32.h` or `time64.h` depending on the definition of `_DLIB_TIME_USES_64`.

  If `_DLIB_TIME_USES_64` is:

  - defined to 1, it will include `time64.h`.
  - defined to 0, it will include `time32.h`.
  - undefined, it will include `time32.h`.

In both interfaces, `time_t` starts at the year 1970.

An application can use either interface, and even mix them by explicitly using the 32 or 64-bit variants.

See also *__time32, __time64*, page 155.

`clock_t` is represented by a 32-bit integer type.

By default, the time library does not support the timezone and daylight saving time functionality. To enable that functionality, use the linker option `--timezone_lib`. See *--timezone_lib*, page 323.

There are two functions that can be used for loading or force-loading the timezone and daylight saving time information from `__getzone`:

- `int _ReloadDstRules (void)`
- `int _ForceReloadDstRules (void)`

Both these functions return `0` for DST rules found and `-1` for DST rules not found.

NON-STANDARD IMPLEMENTATIONS

These functions do not work as specified by the C standard:

- `fopen_s` and `freopen`

  These functions will not propagate the `u` exclusivity attribute to the low-level interface.
- `towupper` and `towlower`

  These functions will only handle `A`, `...`, `Z` and `a`, `...`, `z`.
- `iswalnum`, `...`, `iswxdigit`

  These functions will only handle arguments in the range 0 to 127.
- The collate functions `strcoll` and `strxfrm` will not work as intended. The same applies to the C++ equivalent functionality.

SYMBOLS USED INTERNALLY BY THE LIBRARY

The system header files use intrinsic functions, symbols, pragma directives etc. Some are defined in the library and some in the compiler. These reserved symbols start with __ (double underscores) and should only be used by the library.

Use the compiler option `--predef_macros` to determine the value for any predefined symbols.

The symbols used internally by the library are not listed in this guide.

The linker configuration file

- Overview
- Declaring the build type
- Defining memories and regions
- Regions
- Section handling
- Section selection
- Using symbols, expressions, and numbers
- Structural configuration

Before you read this chapter you must be familiar with the concept of *sections*, see *Modules and sections*, page 90.

Overview

To link and locate an application in memory according to your requirements, ILINK needs information about how to handle sections and how to place them into the available memory regions. In other words, ILINK needs a *configuration*, passed to it by means of the *linker configuration file*.

This file consists of a sequence of directives and typically, provides facilities for:

- Declaring the build type

  informing the linker of whether the build is for a traditional ROM system or for a RAM system, helping the linker check that only suitable sections are placed in the different memory regions.
- Defining available addressable memories

  giving the linker information about the maximum size of possible addresses and defining the available physical memory, as well as dealing with memories that can be addressed in different ways.

- Defining the regions of the available memories that are populated with ROM or RAM

  giving the start and end address for each region.
- Section groups

  dealing with how to group sections into blocks and overlays depending on the section requirements.
- Defining how to handle initialization of the application

  giving information about which sections that are to be initialized, and how that initialization should be made.
- Memory allocation

  defining where—in what memory region—each set of sections should be placed.
- Using symbols, expressions, and numbers

  expressing addresses and sizes, etc, in the other configuration directives. The symbols can also be used in the application itself.
- Structural configuration

  meaning that you can include or exclude directives depending on a condition, and to split the configuration file into several different files.
- Special characters in names

  When specifying the name of a symbol or section that uses non-identifier characters, you can enclose the name in back quotes. Example: `` `My Name` ``.

Comments can be written either as C comments (`/*...*/`) or as C++ comments (`//...`).

Declaring the build type

Declaring the build type in the linker configuration files specifies to the linker whether the build is for a traditional ROM system (with, among other things, variable initialization at program start) or for a RAM system to be used for debugging (where other styles of initialization can be used).

build for directive

Syntax

```
build for { ram | rom };
```

Parameters

`ram`	The build is assumed to be a debugging or experimental setup, where some or all variable initialization can be performed at load time.
`rom`	The build is assumed to be a traditional ROM build, where all variable initialization is performed at program start.

Description

If you declare a build type of `rom`—and especially if you also declare which memory regions are ROM or RAM—the linker can perform better checking that only suitable sections are placed in the different memory regions. If you do not explicitly specify an `initialize` directive (see *initialize directive*, page 440), the linker will behave as if you had specified `initialize by copy { rw };`.

If you declare a build type of `ram`, the linker does not check which section types are placed in which memory region.

If you do not include the `build for` directive in the linker configuration file, the linker only performs limited checking. This is useful primarily for backward compatibility purposes.

See also

define region directive, page 426.

Defining memories and regions

ILINK needs information about the available memory spaces, or more specifically it needs information about:

- The maximum size of possible addressable memories

  The `define memory` directive defines a *memory space* with a given size, which is the maximum possible amount of addressable memory, not necessarily physically available. See *define memory directive*, page 426.
- Available physical memory

  The `define region` directive defines a region in the available memories in which specific sections of application code and sections of application data can be placed. You can also use this directive to declare whether a region contains RAM or ROM memory. This is primarily useful when building for a traditional ROM system. See *define region directive*, page 426.

A region consists of one or several memory ranges. A range is a continuous sequence of bytes in a memory and several ranges can be expressed by using region expressions. See *Region expression*, page 430.

This section gives detailed information about each linker directive specific to defining memories and regions.

define memory directive

Syntax

```
define memory [ name ] with size = size_expr [ ,unit-size ];
```

where `unit-size` is one of:

```
unitbitsize = bitsize_expr
unitbytesize = bytesize_expr
```

and where `expr` is an expression, see *expressions*, page 453.

Parameters

size_expr	Specifies how many *units* the memory space contains—always counted from address zero.
bitsize_expr	Specifies how many bits each unit contains.
bytesize_expr	Specifies how many bytes each unit contains. Each byte contains 8 bits.

Description

The `define memory` directive defines a *memory space* with a given size, which is the maximum possible amount of addressable memory, not necessarily physically available. This sets the limits for the possible addresses to be used in the linker configuration file. For many microcontrollers, one memory space is sufficient. However, some microcontrollers require two or more. For example, a Harvard architecture usually requires two different memory spaces, one for code and one for data. If only one memory is defined, the memory name is optional. If no `unit-size` is given, the unit contains 8 bits.

Example

```
/* Declare the memory space Mem of four Gigabytes */
define memory Mem with size = 4G;
```

define region directive

Syntax

```
define [ ram | rom ] name = region-expr;
```

where `region-expr` is a region expression, see also *Regions*, page 429.

Parameters

`ram`	The region contains RAM memory.
`rom`	The region contains ROM memory.
`name`	The name of the region.

Description

The `define region` directive defines a region in which specific sections of code and sections of data can be placed. A region consists of one or several memory ranges, where each memory range consists of a continuous sequence of bytes in a specific memory. Several ranges can be combined by using region expressions—these ranges do not need to be consecutive or even in the same memory.

If you declare regions as being ROM or RAM, the linker can check that only suitable sections are placed in the regions if you are building a traditional ROM-based system (see *build for directive*, page 425).

Example

```
/* Define the 0x10000-byte code region ROM located at address
   0x10000 */
define rom region ROM = [from 0x10000 size 0x10000];
```

logical directive

Syntax

`logical` *`range-list`* `= physical` *`range-list`*

where *`range-list`* is one of

```
[ region-expr,... ]region-expr
[ region-expr,... ]from address-expr
```

Parameters

`region-expr`	A region expression, see also *Regions*, page 429.
`address-expr`	An address expression

Description

The `logical` directive maps logical addresses to physical addresses. The physical address is typically used when loading or burning content into memory, while the logical address is the one seen by your application. The physical address is the same as the logical address, if no `logical` directives are used, or if the address is in a range specified in a `logical` directive.

When generating ELF output, the mapping affects the physical address in program headers. When generating output in the Intel hex or Motorola S-records formats, the physical address is used.

Each address in the logical range list, in the order specified, is mapped to the corresponding address in the physical range list, in the order specified.

Unless one or both of the range lists end with the `from` form, the total size of the logical ranges and the physical ranges must be the same. If one side ends with the `from` form and not the other, the side that ends with the `from` form will include a final range of a size that makes the total sizes match, if possible. If both sides end with a `from` form, the ranges will extend to the highest possible address that makes the total sizes match.

Setting up a mapping from logical to physical addresses can affect how sections and other content are placed. No content will be placed to overlap more than one individual logical or physical range. Also, if there is a mapping from a different logical range to the corresponding physical range, any logical range for which no mapping to physical ranges has been specified—by not being mentioned in a `logical` directive—is excluded from placement.

All `logical` directives are applied together. Using one or using several directives to specify the same mapping makes no difference to the result.

Example

```
// Logical range 0x8000-0x8FFF maps to physical 0x10000-0x10FFF.
// No content can be placed in the logical range 0x10000-0x10FFF.
logical [from 0x8000 size 4K] = physical [from 0x10000 size 4K];

// Another way to specify the same mapping
logical [from 0x8000 size 4K] = physical from 0x10000;

// Logical range 0x8000-0x8FFF maps to physical 0x10000-0x10FFF.
// Logical range 0x10000-0x10FFF maps to physical 0x8000-0x8FFF.
// No logical range is excluded from placement because of
// this mapping.
logical [from  0x8000 size 4K] = physical [from 0x10000 size 4K];
logical [from 0x10000 size 4K] = physical [from  0x8000 size 4K];

// Logical range 0x1000-0x13FF maps to physical 0x8000-0x83FF.
// Logical range 0x1400-0x17FF maps to physical 0x9000-0x93FF.
// Logical range 0x1800-0x1BFF maps to physical 0xA000-0xA3FF.
// Logical range 0x1C00-0x1FFF maps to physical 0xB000-0xB3FF.
// No content can be placed in the logical ranges 0x8000-0x83FF,
// 0x9000-0x9FFF, 0xA000-0xAFFF, or 0xB000-0xBFFF.
logical [from 0x1000 size 4K] =
   physical [from 0x8000 size 1K repeat 4 displacement 4K];
```

```
// Another way to specify the same mapping.
logical [from 0x1000 to 0x13FF] = physical [from 0x8000 to 
0x83FF];
logical [from 0x1400 to 0x17FF] = physical [from 0x9000 to 
0x93FF];
logical [from 0x1800 to 0x1BFF] = physical [from 0xA000 to 
0xA3FF];
logical [from 0x1C00 to 0x1FFF] = physical [from 0xB000 to 
0xB3FF];
```

Regions

A *region* is s a set of non-overlapping memory ranges. A *region expression* is built up out of *region literals* and set operations (union, intersection, and difference) on regions.

Region literal

Syntax

[`memory-name`: **]**[from `expr` **{** to `expr` **|** size `expr` **}**

[repeat `expr` **[** displacement `expr` **]]**]

where `expr` is an expression, see *expressions*, page 453.

Parameters

`memory-name`	The name of the memory space in which the region literal will be located. If there is only one memory, the name is optional.
`from expr`	`expr` is the start address of the memory range (inclusive).
`to expr`	`expr` is the end address of the memory range (inclusive).
`size expr`	`expr` is the size of the memory range.
`repeat expr`	`expr` defines several ranges in the same memory for the region literal.
`displacement expr`	`expr` is the displacement from the previous range start in the repeat sequence. Default displacement is the same value as the range size.

Description

A region literal consists of one memory range. When you define a range, the memory it resides in, a start address, and a size must be specified. The range size can be stated explicitly by specifying a size, or implicitly by specifying the final address of the range. The final address is included in the range and a zero-sized range will only contain an address. A range can span over the address zero and such a range can even be expressed by unsigned values, because it is known where the memory wraps.

The `repeat` parameter will create a region literal that contains several ranges, one for each repeat. This is useful for *banked* or *far* regions.

Example

```
/* The 5-byte size range spans over the address zero */
Mem:[from -2 to 2]

/* The 512-byte size range spans over zero, in a 64-Kbyte memory
*/
Mem:[from 0xFF00 to 0xFF]

/* Defining several ranges in the same memory, a repeating
   literal */
Mem:[from 0 size 0x100 repeat 3 displacement 0x1000]

/* Resulting in a region containing:
   Mem:[from 0 size 0x100]
   Mem:[from 0x1000 size 0x100]
   Mem:[from 0x2000 size 0x100]
*/
```

See also

define region directive, page 426, and *Region expression*, page 430.

Region expression

Syntax

```
region-operand
 | region-expr | region-operand
 | region-expr - region-operand
 | region-expr & region-operand
```

where *`region-operand`* is one of:

```
( region-expr )
region-name
region-literal
empty-region
```

where *`region-name`* is a region, see *define region directive*, page 426

where *`region-literal`* is a region literal, see *Region literal*, page 429

and where *`empty-region`* is an empty region, see *Empty region*, page 431.

Description

Normally, a region consists of one memory range, which means a *region literal* is sufficient to express it. When a region contains several ranges, possibly in different memories, it is instead necessary to use a *region expression* to express it. Region expressions are actually set expressions on sets of memory ranges.

To create region expressions, three operators are available: union (|), intersection (&), and difference (-). These operators work as in *set theory*. For example, if you have the sets A and B, then the result of the operators would be:

- `A | B`: all elements in either set A or set B
- `A & B`: all elements in both set A and B
- `A - B`: all elements in set A but not in B.

Example

```
/* Resulting in a range starting at 1000 and ending at 2FFF, in
   memory Mem */
Mem:[from 0x1000 to 0x1FFF] | Mem:[from 0x1500 to 0x2FFF]

/* Resulting in a range starting at 1500 and ending at 1FFF, in
   memory Mem */
Mem:[from 0x1000 to 0x1FFF] & Mem:[from 0x1500 to 0x2FFF]

/* Resulting in a range starting at 1000 and ending at 14FF, in
   memory Mem */
Mem:[from 0x1000 to 0x1FFF] - Mem:[from 0x1500 to 0x2FFF]

/* Resulting in two ranges. The first starting at 1000 and ending
   at 1FFF, the second starting at 2501 and ending at 2FFF.
   Both located in memory Mem */
Mem:[from 0x1000 to 0x2FFF] - Mem:[from 0x2000 to 0x24FF]
```

Empty region

Syntax

```
[ ]
```

Description

The empty region does not contain any memory ranges. If the empty region is used in a placement directive that actually is used for placing one or more sections, ILINK will issue an error.

Example

```
define region Code = Mem:[from 0 size 0x10000];
if (Banked) {
  define region Bank = Mem:[from 0x8000 size 0x1000];
} else {
  define region Bank = [];
}
define region NonBanked = Code - Bank;

/* Depending on the Banked symbol, the NonBanked region is either
   one range with 0x10000 bytes, or two ranges with 0x8000 and
   0x7000 bytes, respectively. */
```

See also

Region expression, page 430.

Section handling

Section handling describes how ILINK should handle the sections of the execution image, which means:

- Placing sections in regions

  The `place at` and `place in` directives place sets of sections with similar attributes into previously defined regions. See *place at directive*, page 443 and *place in directive*, page 445.

- Making sets of sections with special requirements

  The `block` directive makes it possible to create empty sections with specific or expanding sizes, specific alignments, sequentially sorted sections of different types, etc.

  The `overlay` directive makes it possible to create an area of memory that can contain several overlay images. See *define block directive*, page 433, and *define overlay directive*, page 435.

- Initializing the application

  The directives `initialize` and `do not initialize` control how the application should be started. With these directives, the application can initialize global symbols at startup, and copy pieces of code. The initializers can be stored in several ways, for example, they can be compressed. See *initialize directive*, page 440 and *do not initialize directive*, page 439.

- Keeping removed sections

  The `keep` directive retains sections even though they are not referred to by the rest of the application, which means it is equivalent to the *root* concept in the assembler and compiler. See *keep directive*, page 443.

- Specifying the contents of linker-generated sections

  The `define section` directive can be used for creating specific sections with content and calculations that are only available at link time.
- Additional more specialized directives:

  `use init table` directive

This section gives detailed information about each linker directive specific to section handling.

define block directive

Syntax

```
define  block name
  [ with param, param... ]
{
  extended-selectors
}
[ except
 {
   section-selectors
  } ];
```

where *param* can be one of:

```
size = expr
minimum size = expr
maximum size = expr
expanding size
alignment = expr
fixed order
alphabetical order
static base [basename]
```

and where the rest of the directive selects sections to include in the block, see *Section selection*, page 446.

Parameters

name	The name of the block to be defined.
`size`	Customizes the size of the block. By default, the size of a block is the sum of its parts dependent of its contents.
`minimum size`	Specifies a lower limit for the size of the block. The block is at least this large, even if its contents would otherwise not require it.

`maximum size`	Specifies an upper limit for the size of the block. An error is generated if the sections in the block do not fit.
`expanding size`	The block will expand to use all available space in the memory range where it is placed.
`alignment`	Specifies a minimum alignment for the block. If any section in the block has a higher alignment than the minimum alignment, the block will have that alignment.
`fixed order`	Places sections in the specified order. Each *`extended-selector`* is added in a separate nested block, and these blocks are kept in the specified order.
`alphabetical order`	Places sections in alphabetical order by section name. Only *`section-selector`* patterns are allowed in `alphabetical order` blocks, for example, no nested blocks. All sections in a particular `alphabetical order` block must use the same kind of initialization (read-only, zero-init, copy-init, or no-init, and otherwise equivalent). You cannot use `__section_begin`, etc on individual sections contained in an `alphabetical order` block.
`static base [`*`basename`*`]`	Specifies that the static base with the name *`basename`* will be placed at the start of the block or in the middle of the block, as appropriate for the particular static base. The startup code must ensure that the register that holds the static base is initialized to the correct value. If there is only one static base, the name can be omitted.

Description

The `block` directive defines a contiguous area of memory that contains a possibly empty set of sections or other blocks. Blocks with no content are useful for allocating space for stacks or heaps. Blocks with content are usually used to group together sections that must to be consecutive.

You can access the start, end, and size of a block from an application by using the `__section_begin`, `__section_end`, or `__section_size` operators. If there is no block with the specified name, but there are sections with that name, a block will be created by the linker, containing all such sections.

Blocks with expanding size are most often used for heaps or stacks.

Note: You cannot place a block with expanding size inside another block with expanding size, inside a block with a maximum size, or inside an overlay.

Example

```
/* Create a block with a minimum size for the heap that will use
all remaining space in its memory range */
define block HEAP with minimum size = 4K, expanding size,
alignment = 8 { };
```

See also

Interaction between the tools and your application, page 207. For an accessing example, see *define overlay directive*, page 435.

define overlay directive

Syntax

```
define overlay name [ with param, param... ]
{
  extended-selectors;
}
[ except
 {
   section-selectors
  } ];
```

For information about extended selectors and except clauses, see *Section selection*, page 446.

Parameters

name	The name of the overlay.
`size`	Customizes the size of the overlay. By default, the size of a overlay is the sum of its parts dependent of its contents.
`maximum size`	Specifies an upper limit for the size of the overlay. An error is generated if the sections in the overlay do not fit.
`alignment`	Specifies a minimum alignment for the overlay. If any section in the overlay has a higher alignment than the minimum alignment, the overlay will have that alignment.
`fixed order`	Places sections in fixed order—if not specified, the order of the sections will be arbitrary.

Description

The `overlay` directive defines a named set of sections. In contrast to the `block` directive, the overlay directive can define the same name several times. Each definition will then be grouped in memory at the same place as all other definitions of the same name. This creates an *overlaid* memory area, which can be useful for an application that has several independent sub-applications.

Place each sub-application image in ROM and reserve a RAM overlay area that can hold all sub-applications. To execute a sub-application, first copy it from ROM to the RAM overlay.

Note: ILINK does not help you with managing interdependent overlay definitions, apart from generating a diagnostic message for any reference from one overlay to another overlay.

The size of an overlay will be the same size as the largest definition of that overlay name and the alignment requirements will be the same as for the definition with the highest alignment requirements.

Note: Sections that were overlaid must be split into a RAM and a ROM part and you must take care of all the copying needed.

Code in overlaid memory areas cannot be debugged; the C-SPY Debugger cannot determine which code is currently loaded.

See also

Manual initialization, page 113.

define section directive

Syntax

```
define [ root ] section name
  [ with alignment = sec-align ]
{
  section-content-item...
};
```

where each *section-content-item* can be one of:

```
udata8 { data | string };
sdata8 data [ ,data ] ...;
udata16 data [ ,data ] ...;
sdata16 data [ ,data ] ...;
udata24 data [ ,data ] ...;
sdata24 data [ ,data ] ...;
udata32 data [ ,data ] ...;
sdata32 data [ ,data ] ...;
udata64 data [ ,data ] ...;
sdata64 data [ ,data ] ...;
pad_to data-align;
[ public ] label:
if-item;
```

where *if-item* is:

```
if ( condition ) {
   section-content-item...
[} else if (condition] {
   section-content-item... ]...
[} else {
   section-content-item...]
}
```

Parameters

name	The name of the section.
sec-align	The alignment of the section, an expression.
root	Optional. If `root` is specified, the section is always included, even if it is not referenced.
udata8 **{***data*|*string***}**;	If the parameter is an expression (*data*), it generates an unsigned one-byte member in the section. The *data* expression is only evaluated during relocation and only if the value is needed. It causes a relocation error if the value of *data* is too large to fit in a byte. The possible range of values is `0` to `0xFF`. If the parameter is a quoted string, it generates one one-byte member in the section for each character in the string.
sdata8 *data*;	As `udata8` *data*, except that it generates a signed one-byte member. The possible range of values is –`0x80` to `0x7F`.
udata16 *data*;	As `sdata8`, except that it generates an unsigned two-byte member. The possible range of values is `0` to `0xFFFF`.
sdata16 *data*;	As `sdata8`, except that it generates a signed two-byte member. The possible range of values is –`0x8000` to `0x7FFF`.
udata24 *data*;	As `sdata8`, except that it generates an unsigned three-byte member. The possible range of values is `0` to `0xFFFFFF`.
sdata24 *data*;	As `sdata8`, except that it generates a signed three-byte member. The possible range of values is –`0x800000` to `0x7FFFFF`.

`udata32 data;`	As `sdata8`, except that it generates an unsigned four-byte member. The possible range of values is `0` to `0xFFFFFFFF`.
`sdata32 data;`	As `sdata8`, except that it generates a signed four-byte member. The possible range of values is `–0x80000000` to `0x7FFFFFFF`.
`udata64 data;`	As `sdata8`, except that it generates an unsigned eight-byte member. The possible range of values is `0` to `0xFFFFFFFFFFFFFFFF`.
`sdata64 data;`	As `sdata8`, except that it generates a signed eight-byte member. The possible range of values is `-0x8000000000000000` to `0x7FFFFFFFFFFFFFFF`.
`pad_to data_align;`	Generates pad bytes to make the current offset from the start of the section to be aligned to the expression *`data-align`*.
`[public] label:`	Defines a label at the current offset from the start of the section. If `public` is specified, the label is visible to other program modules. If not, it is only visible to other data expressions in the linker configuration file.
`if-item`	Configuration-time selection of items.
`condition`	An expression.
`data`	An expression that is only evaluated during relocation and only if the value is needed.

Description

Use the `define section` directive to create sections with content that is not available from assembler language or C/C++. Examples of this are the results of stack usage analysis, the size of blocks, and arithmetic operations that do not exist as relocations.

Unknown identifiers in data expressions are assumed to be labels.

Note: Only data expressions can use labels, stack usage analysis results, etc. All the other expressions are evaluated immediately when the configuration file is read.

Example

```
define section data {
```

```
  /* The application entry in a 16-bit word, provided it is less
     than 256K and 4-byte aligned. */
  udata16 __iar_program_start >> 2;
  /* The maximum stack usage in the program entry category. */
  udata16 maxstack("Application entry");
  /* The size of the DATA block */
  udata32 size(block DATA);
};
```

do not initialize directive

Syntax

```
do not initialize
{
  section-selectors
}
[ except
 {
   section-selectors
 } ];
```

For information about section selectors and except clauses, see *Section selection*, page 446.

Description

Use the `do not initialize` directive to specify the sections that you do not want to be automatically zero-initialized by the system startup code. The directive can only be used on `zeroinit` sections.

Typically, this is useful if you want to handle zero-initialization in some other way for all or some `zeroinit` sections.

This can also be useful if you want to suppress zero-initialization of variables entirely. Normally, this is handled automatically for variables specified as `__no_init` in the source, but if you link with object files produced by older tools from IAR Systems or other tool vendors, you might need to suppress zero-initialization specifically for some sections.

Example

```
/* Do not initialize read-write sections whose name ends with
   _noinit at program start */
do not initialize { rw section .*_noinit };
place in RAM { rw section .*_noinit };
```

See also

Initialization at system startup, page 96, and *initialize directive*, page 440.

initialize directive

Syntax

```
initialize { by copy | manually }
  [ with param, param... ]
{
  section-selectors
}
[ except
 {
   section-selectors
 } ];
```

where *param* can be one of:

```
packing = algorithm
simple ranges
complex ranges
no exclusions
```

For information about section selectors and except clauses, see *Section selection*, page 446.

Parameters

`by copy`	Splits the section into sections for initializers and initialized data, and handles the initialization at application startup automatically.
`manually`	Splits the section into sections for initializers and initialized data. The initialization at application startup is not handled automatically.

algorithm	Specifies how to handle the initializers. Choose between: `none` - Disables compression of the selected section contents. This is the default method for initialize manually. `zeros` - Compresses consecutive bytes with the value zero. `packbits` - Compresses with the PackBits algorithm. This method generates good results for data with many identical consecutive bytes. `lz77` - Compresses with the Lempel-Ziv-77 algorithm. This method handles a larger variety of inputs well, but has a slightly larger decompressor. `auto` - ILINK estimates the resulting size using each packing method (except for `auto`), and then chooses the packing method that produces the smallest estimated size. Note that the size of the decompressor is also included. This is the default method for `initialize by copy`. `smallest` - This is a synonym for `auto`.

Description

The `initialize` directive splits each selected section into one section that holds initializer data and another section that holds the space for the initialized data. The section that holds the space for the initialized data retains the original section name, and the section that holds initializer data gets the name suffix `_init`. You can choose whether the initialization at startup should be handled automatically (`initialize by copy`) or whether you should handle it yourself (`initialize manually`).

When you use the packing method `auto` (default for `initialize by copy`), ILINK will automatically choose an appropriate packing algorithm for the initializers. To override this, specify a different `packing` method. The `--log initialization` option shows how ILINK decided which packing algorithm to use.

When initializers are compressed, a decompressor is automatically added to the image.

Each decompressor has two variants: one that can only handle a single source and destination range at a time, and one that can handle more complex cases. By default, the linker chooses a decompressor variant based on whether the associated section placement directives specify a single or multi-range memory region. In general, this is the desired behavior, but you can use the `with complex ranges` or the `with simple ranges` modifier on an `initialize` directive to specify which decompressor variant to use. You can also use the command line option `--default_to_complex_ranges` to make `initialize` directives by default use complex ranges. The `simple ranges` decompressors are normally hundreds of bytes smaller than the `complex ranges` variants.

When initializers are compressed, the exact size of the compressed initializers is unknown until the exact content of the uncompressed data is known. If this data contains other addresses, and some of these addresses are dependent on the size of the compressed initializers, the linker fails with error Lp017. To avoid this, place compressed initializers last, or in a memory region together with sections whose addresses do not need to be known.

Due to an internal dependence, generation of compressed initializers can also fail (with error LP021) if the address of the initialized area depends on the size of its initializers. To avoid this, place the initializers and the initialized area in different parts of the memory (for example, the initializers are placed in ROM and the initialized area in RAM).

If you specify the parameter `no exclusions`, an error is emitted if any sections are excluded (because they are needed for the initialization). `no exclusions` can only be used with `initialize by copy` (automatic initialization), not with `initialize manually`.

Unless `initialize manually` is used, ILINK will arrange for initialization to occur during system startup by including an initialization table. Startup code calls an initialization routine that reads this table and performs the necessary initializations.

Zero-initialized sections are not affected by the `initialize` directive.

The `initialize` directive is normally used for initialized variables, but can be used for copying any sections, for example, copying executable code from slow ROM to fast RAM, or for overlays. For another example, see *define overlay directive*, page 435.

Sections that are needed for initialization are not affected by the `initialize by copy` directive. This includes the `__low_level_init` function and anything it references.

Anything reachable from the program entry label is considered *needed for initialization* unless reached via a section fragment with a label starting with `__iar_init$$done`. The `--log sections` option, in addition to logging the marking of section fragments to be included in the application, also logs the process of determining which sections are needed for initialization.

Example

```
/* Copy all read-write sections automatically from ROM to RAM at
   program start */
initialize by copy { rw };
place in RAM { rw };
place in ROM { ro };
```

See also

Initialization at system startup, page 96, and *do not initialize directive*, page 439.

keep directive

Syntax

```
keep
{
  [ { section-selectors | block name }
    [ , {section-selectors | block name }... ] ]
}
[ except
 {
   section-selectors
 } ];
```

For information about selectors and except clauses, see *Section selection*, page 446.

Description

The `keep` directive can be used for including blocks, overlays, or sections in the executable image that would otherwise be discarded because no references to them exist in the included parts of the application. Note that only sections from included modules are considered for inclusion.

The `keep` directive does not cause any additional *modules* to be included in the application. To cause modules that define the specified symbols to be included, use the **Keep symbols** linker option (or the `--keep` command line option).

Example

```
keep { section .keep* } except {section .keep};
```

place at directive

Syntax

```
[ "name": ]
place [ noload ] at { address [ memory: ] address |
      start of region_expr [ with mirroring to mirror_address ] |
      end of region_expr [ with mirroring to mirror_address ] }

{
  extended-selectors
}
[ except
 {
   section-selectors
 } ];
```

For information about extended selectors and except clauses, see *Section selection*, page 446.

Parameters

name	Optional. If it is specified, it is used in the map file, in some log messages, and is part of the name of any ELF output sections resulting from the directive.
`noload`	Optional. If it is specified, it prevents the sections in the directive from being loaded to the target system. To use the sections, you must put them into the target system in some other way. `noload` can only be used when a *name* is specified.
memory: *address*	A specific address in a specific memory. The address must be available in the supplied memory defined by the `define memory` directive. The memory specifier is optional if there is only one memory.
`start of` *region_expr*	A region expression that results in a single-internal region. The start of the interval is used.
`end of` *region_expr*	A region expression that results in a single-internal region. The end of the interval is used.
mirror_address	If `with mirroring to` is specified, the contents of any sections are assumed to be mirrored to this address, therefore debug information and symbols will appear in the mirrored range, but the actual content bytes are placed as if `with mirroring to` was not specified. **Note:** This functionality is intended to support external (target-specific) mirroring.

Description

The `place at` directive places sections and blocks either at a specific address or, at the beginning or the end of a region. The same address cannot be used for two different `place at` directives. It is also not possible to use an empty region in a `place at` directive. If placed in a region, the sections and blocks will be placed before any other sections or blocks placed in the same region with a `place in` directive.

Note: `with mirroring to` can be used only together with `start of` and `end of`.

Example

```
/* Place the RO section .startup at the start of code_region */
"START": place at start of ROM { readonly section .startup };
```

See also

place in directive, page 445.

place in directive

Syntax

```
[ "name": ]
place [ noload ] in region-expr
      [ with mirroring to mirror_address ]
{
  extended-selectors
}
 [ except{
   section-selectors
 } ];
```

where `region-expr` is a region expression, see also *Regions*, page 429.

and where the rest of the directive selects sections to include in the block. See *Section selection*, page 446.

Parameters

name	Optional. If it is specified, it is used in the map file, in some log messages, and is part of the name of any ELF output sections resulting from the directive.
`noload`	Optional. If it is specified, it prevents the sections in the directive from being loaded to the target system. To use the sections, you must put them into the target system in some other way. `noload` can only be used when a *name* is specified.
mirror_address	If `with mirroring to` is specified, the contents of any sections are assumed to be mirrored to this address, therefore debug information and symbols will appear in the mirrored range, but the actual content bytes are placed as if `with mirroring to` was not specified. **Note:** This functionality is intended to support external (target-specific) mirroring.

Description

The `place in` directive places sections and blocks in a specific region. The sections and blocks will be placed in the region in an arbitrary order.

To specify a specific order, use the `block` directive. The region can have several ranges.

Note: When `with mirroring to` is specified, the `region-expr` must result in a single range.

Example

```
/* Place the read-only sections in the code_region */
"ROM": place in ROM { readonly };
```

See also *place at directive*, page 443.

use init table directive

Syntax

```
use init table name for
{
  section-selectors
}
[ except
 {
   section-selectors
 } ];
```

For information about section selectors and except clauses, see *Section selection*, page 446.

Parameters

name	The name of the `init` table.

Description

Normally, all initialization entries are generated into a single initialization table (called `Table`). Use this directive to cause some of the entries to be put into a separate table. You can then use this initialization table at another time, or under different circumstances, than the normal initialization table.

Initialization entries for all variables not mentioned in a `use init table` directive are put into the normal initialization table. By having multiple `use init table` directives you can have multiple initialization tables.

The start, end, and size of the `init` table can be accessed in the application program by using `__section_begin`, `__section_end`, or `__section_size` of `"Region$$name"`, respectively, or via the symbols `Region$$name$$Base`, `Region$$name$$Limit`, and `Region$$name$$Length`.

Example

```
use init table Core2 for { section *.core2};

/* __section_begin("Region$$Core2") can be used to get the start
   of the Core2 init table. */
```

Section selection

The purpose of *section selection* is to specify—by means of *section selectors* and *except clauses*—the sections that an ILINK directive should be applied to. All sections that match one or more of the section selectors will be selected, and none of the sections selectors in the except clause, if any. Each section selector can match sections on section attributes, section name, and object or library name.

Some directives provide functionality that requires more detailed selection capabilities, for example, directives that can be applied on both sections and blocks. In this case, the *extended-selectors* are used.

This section gives detailed information about each linker directive specific to section selection.

section-selectors

Syntax

```
[ section-selector [ , section-selector... ] ]
```

section-selector is:

```
[ section-attribute ][ section-type ]
[ symbol symbol-name ][ section section-name ]
[ object module-spec ]
```

section-attribute is:

```
ro [ code | data ] | rw [ code | data ] | zi
```

section-type is:

```
[ preinit_array | init_array ]
```

Parameters

`section-attribute` — Only sections with the specified attribute will be selected. `section-attribute` can consist of:

`ro|readonly`, for ROM sections.
`rw|readwrite`, for RAM sections.

In each category, sections can be further divided into those that contain code and those that contain data, resulting in four main categories:

`ro code`, for normal code
`ro data`, for constants
`rw code`, for code copied to RAM
`rw data`, for variables

`readwrite data` also has a subcategory—`zi|zeroinit`—for sections that are zero-initialized at application startup.

section-type — Only sections with that ELF section type will be selected. *section-type* can be:

`preinit_array`, sections of the ELF section type `SHT_PREINIT_ARRAY`.

`init_array`, sections of the ELF section type `SHT_INIT_ARRAY`.

`symbol` *symbol-name* — Only sections that define at least one public symbol that matches the symbol name pattern will be selected. *symbol-name* is the symbol name pattern. Two wildcards are allowed:

`?` matches any single character.

`*` matches zero or more characters.

`section` *section-name* — Only sections whose names match the *section-name* will be selected. Two wildcards are allowed:

`?` matches any single character

`*` matches zero or more characters.

`object` *module-spec* — Only sections that originate from library modules or object files that matches *module-spec* will be selected. *module-spec* can be in one of two forms:

module, a name in the form *objectname*(*libraryname*). Sections from object modules where both the object name and the library name match their respective patterns are selected. An empty library name pattern selects only sections from object files. If *libraryname* is `:sys`, the pattern will match only sections from the system library.

filename, the name of an object file, or an object in a library.

Two wildcards are allowed:

`?` matches any single character

`*` matches zero or more characters.

Description

A section selector selects all sections that match the section attribute, section type, symbol name, section name, and the name of the module. Up to four of the five conditions can be omitted.

It is also possible to use only `{ }` without any section selectors, which can be useful when defining blocks.

Note: A section selector with narrower scope has higher priority than a more generic section selector. If more than one section selector matches for the same purpose, one of them must be more specific. A section selector is more specific than another one if in priority order:

- It specifies a symbol name with no wildcards and the other one does not.
- It specifies a section name or object name with no wildcards and the other one does not
- It specifies a section type and the other one does not
- There could be sections that match the other selector that also match this one, however, the reverse is not true.

Selector 1	Selector 2	More specific
`ro`	`ro code`	Selector 2
`symbol mysym`	`section foo`	Selector 1
`ro code section f*`	`ro section f*`	Selector 1
`section foo*`	`section f*`	Selector 1
`section *x`	`section f*`	Neither
`init_array`	`section f*`	Selector 1
`section .intvec`	`ro section .int*`	Selector 1
`section .intvec`	`object foo.o`	Neither

Table 35: Examples of section selector specifications

Example

```
{ rw }                      /* Selects all read-write sections */

{ section .mydata* }        /* Selects only .mydata* sections */
/* Selects .mydata* sections available in the object special.o */
{ section .mydata* object special.o }
```

Assuming a section in an object named `foo.o` in a library named `lib.a`, any of these selectors will select that section:

```
object foo.o(lib.a)
object f*(lib*)
object foo.o
object lib.a
```

See also

initialize directive, page 440, *do not initialize directive*, page 439, and *keep directive*, page 443.

extended-selectors

Syntax

```
[ extended-selector [ , extended-selector...]]
```

where *extended-selector* is:

```
[ first | last | midway ]
                     { section-selector |
                       block name [ inline-block-def ] |
                       overlay name }
```

where *inline-block-def* is:

```
[ block-params ] extended-selectors
```

Parameters

`first`	Places the selected sections, block, or overlay first in the containing placement directive, block, or overlay.
`last`	Places the selected sections, block or overlay last in the containing placement directive, block, or overlay.
`midway`	Places the selected sections, block, or overlay so that they are no further than half the maximum size of the containing block away from either edge of the block. Note that this parameter can only be used inside a block that has a maximum size.
name	The name of the block or overlay.

Description

Use `extended-selectors` to select content for inclusion in a placement directive, block, or overlay. In addition to using section selection patterns, you can also explicitly specify blocks or overlays for inclusion.

Using the `first` or `last` keyword, you can specify one pattern, block, or overlay that is to be placed first or last in the containing placement directive, block, or overlay. If you need more precise control of the placement order you can instead use a block with fixed order.

Blocks can be defined separately, using the `define block` directive, or inline, as part of an `extended-selector`.

The `midway` parameter is primarily useful together with a static base that can have both negative and positive offsets.

Example

```
define block First { ro section .f* }; /* Define a block holding
                                          any read-only section*/
                                          matching ".f*" */
define block Table { first block First, ro section .b };
                                       /* Define a block where
                                          the block First comes
                                          before the sections
                                          matching ".b*". */
```

You can also define the block `First` inline, instead of in a separate `define block` directive:

```
define block Table { first block First { ro section .f* },
                     ro section .b* };
```

See also

define block directive, page 433, *define overlay directive*, page 435, and *place at directive*, page 443.

Using symbols, expressions, and numbers

In the linker configuration file, you can also:

- *Define and export symbols*

  The `define symbol` directive defines a symbol with a specified value that can be used in expressions in the configuration file. The symbol can also be exported to be used by the application or the debugger. See *define symbol directive*, page 452, and *export directive*, page 453.
- *Use expressions and numbers*

  In the linker configuration file, expressions and numbers are used for specifying addresses, sizes, etc. See *expressions*, page 453.

This section gives detailed information about each linker directive specific to defining symbols, expressions and numbers.

check that directive

Syntax

```
check that expression;
```

Parameters

expression	A boolean expression.

Description

You can use the `check that` directive to compare the results of stack usage analysis against the sizes of blocks and regions. If the expression evaluates to zero, an error is emitted.

Three extra operators are available for use only in `check that` expressions:

`maxstack(`*`category`*`)`	The stack depth of the deepest call chain for any call graph root function in the category.
`totalstack(`*`category`*`)`	The sum of the stack depths of the deepest call chains for each call graph root function in the category.
`size(`*`block`*`)`	The size of the block.

Example

```
check that maxstack("Program entry")
             + totalstack("interrupt")
             + 1K
           <= size(block CSTACK);
```

See also

Stack usage analysis, page 99.

define symbol directive

Syntax

```
define [ exported ] symbol name = expr;
```

Parameters

`exported`	Exports the symbol to be usable by the executable image.
`name`	The name of the symbol.
`expr`	The symbol value.

Description

The `define symbol` directive defines a symbol with a specified value. The symbol can then be used in expressions in the configuration file. The symbols defined in this way work exactly like the symbols defined with the option `--config_def` outside of the configuration file.

The `define exported symbol` variant of this directive is a shortcut for using the directive `define symbol` in combination with the `export symbol` directive. On the command line this would require both a `--config_def` option and a `--define_symbol` option to achieve the same effect.

Note:

- A symbol cannot be redefined
- Symbols that are either prefixed by _X, where X is a capital letter, or that contain __ (double underscore) are reserved for toolset vendors.

Example

```
/* Define the symbol my_symbol with the value 4 */
define symbol my_symbol = 4;
```

See also

export directive, page 453 and *Interaction between ILINK and the application*, page 116.

export directive

Syntax

```
export symbol name;
```

Parameters

name	The name of the symbol.

Description

The `export` directive defines a symbol to be exported, so that it can be used both from the executable image and from a global label. The application, or the debugger, can then refer to it for setup purposes etc.

Example

```
/* Define the symbol my_symbol to be exported */
export symbol my_symbol;
```

expressions

Syntax

An expression is built up of the following constituents:

```
expression binop expression
unop expression
expression ? expression : expression
(expression)
number
symbol
func-operator
```

where *binop* is one of these binary operators:

`+, -, *, /, %, <<, >>, <, >, ==, !=, &, ^, |, &&, ||`

where `unop` is one of this unary operators:

`+, -, !, ~`

where *number* is a number, see *numbers*, page 454

where *symbol* is a defined symbol, see *define symbol directive*, page 452 and *--config_def*, page 300

and where *func-operator* is one of these function-like operators:

`minimum(`*expr*`,`*expr*`)`	Returns the smallest of the two parameters.
`maximum(`*expr*`,`*expr*`)`	Returns the largest of the two parameters.
`isempty(`*r*`)`	Returns True if the region is empty, otherwise False.
`isdefinedsymbol(`*expr-symbol*`)`	Returns True if the expression symbol is defined, otherwise False.
`start(`*r*`)`	Returns the lowest address in the region.
`end(`*r*`)`	Returns the highest address in the region.
`size(`*r*`)`	Returns the size of the complete region.
`isbuildfor(` **{** `ram` **|** `rom` **}** `)`	Returns True if the build type is the one specified, otherwise False.

where *expr* is an expression, and *r* is a region expression, see *Region expression*, page 430.

Description

In the linker configuration file, an expression is a 65-bit value with the range -2^64 to 2^64. The expression syntax closely follows C syntax with some minor exceptions. There are no assignments, casts, pre or post-operations, and no address operations (`*`, `&`, `[]`, `->`, and `.`). Some operations that extract a value from a region expression, etc, use a syntax resembling that of a function call. A boolean expression returns 0 (False) or 1 (True).

numbers

Syntax

nr [*nr-suffix*]

where `nr` is either a decimal number or a hexadecimal number (`0x...` or `0X...`).

and where *nr-suffix* is one of:

```
K          /* Kilo = (1 << 10) 1024 */
M          /* Mega = (1 << 20) 1048576 */
G          /* Giga = (1 << 30) 1073741824 */
T          /* Tera = (1 << 40) 1099511627776 */
P          /* Peta = (1 << 50) 1125899906842624 */
```

Description

A number can be expressed either by normal C means or by suffixing it with a set of useful suffixes, which provides a compact way of specifying numbers.

Example

`1024` is the same as `0x400`, which is the same as `1K`.

Structural configuration

The structural directives provide means for creating structure within the configuration, such as:

- Conditional inclusion

  An `if` directive includes or excludes other directives depending on a condition, which makes it possible to have directives for several different memory configurations in the same file. See *if directive*, page 456.
- Dividing the linker configuration file into several different files

  The `include` directive makes it possible to divide the configuration file into several logically distinct files. See *include directive*, page 456.
- Signaling an error for unsupported cases

This section gives detailed information about each linker directive specific to structural configuration.

error directive

Syntax

`error` *`string`*

Parameters

`string`	The error message.

Description

An `error` directive can be used for signaling an error if the directive occurs in the active part of a conditional directive.

Example

```
error "Unsupported configuration"
```

if directive

Syntax

```
if (expr) {
  directives
[ } else if (expr) {
  directives ]
[ } else {
  directives ]
}
```

where `expr` is an expression, see *expressions*, page 453.

Parameters

directives	Any ILINK directive.

Description

An `if` directive includes or excludes other directives depending on a condition, which makes it possible to have directives for several different memory configurations, for example, both a banked and non-banked memory configuration, in the same file.

The text inside a non-selected part of an `if` directive is not checked for syntax. The only requirements for such text, is that it can be tokenized, and that any open brace (`{`) token has a matching close brace (`}`) token.

Example

See *Empty region*, page 431.

include directive

Syntax

```
include "filename";
```

Parameters

filename	A path where both / and \ can be used as the directory delimiter.

Description

The `include` directive makes it possible to divide the configuration file into several logically distinct parts, each in a separate file. For instance, there might be parts that you need to change often and parts that you seldom edit.

Normally, the linker searches for configuration include files in the system configuration directory. You can use the `--config_search` linker option to add more directories to search.

See also

--config_search, page 300

Section reference

- Summary of sections
- Descriptions of sections and blocks

For more information, see the chapter *Modules and sections*, page 90.

Summary of sections

The compiler places code and data into sections. Based on a configuration specified in the linker configuration file, ILINK places sections in memory.

This table lists the ELF sections and blocks that are used by the IAR build tools:

Section	Description
`CSTACK`	Holds the stack used by C or C++ programs, for single-core G3 devices.
`CSTACK0`	Holds a core-specific stack for multicore devices.
`CSTACK1`	Holds a core-specific stack for multicore devices.
`CSTACK2`	Holds a core-specific stack for multicore devices.
`CSTACK3`	Holds a core-specific stack for multicore devices.
`CSTACK4`	Holds a core-specific stack for multicore devices.
`CSTACK5`	Holds a core-specific stack for multicore devices.
`CSTACK6`	Holds a core-specific stack for multicore devices.
`CSTACK7`	Holds a core-specific stack for multicore devices.
`.bss`	Holds zero-initialized `__huge` static and global variables.
`.const`	Holds `__huge` constant data.
`.data`	Holds `__huge` static and global initialized variables.
`.data_init`	Holds initial values for `.hdata` sections when the linker directive `initialize` is used.
`.data.noinit`	Holds `__no_init __huge` static and global variables.
`HEAP`	Holds the heap used for dynamically allocated data.
`__iar_tls$$DATA`	Holds initial values for TLS variables.
`.iar.dynexit`	Holds the `atexit` table.
`.init_array`	Holds a table of dynamic initialization functions.

Table 36: Section summary

Section	Description
.preinit_array	Holds a table of dynamic initialization functions.
.reset	Holds the reset vector table.
.sbss	Holds zero-initialized __brel static and global variables.
.sbss23	Holds zero-initialized __brel23 static and global variables.
.sconst	Holds __brel constant data.
.sconst23	Holds __brel23 constant data.
.sdata	Holds __brel static and global initialized variables.
.sdata_init	Holds initial values for .sdata sections when the linker directive initialize is used.
.sdata.noinit	Holds __no_init __brel static and global variables.
.sdata23	Holds __brel23 static and global initialized variables.
.sdata23_init	Holds initial values for .sdata23 sections when the linker directive initialize is used.
.sdata23.noinit	Holds __no_init __brel23 static and global variables.
.table.callt	Holds the vector table for __callt functions.
.table.fetrap	Holds the vector table for __fetrap functions.
.table.syscall	Holds the vector table for __syscall functions.
.table.trap	Holds the vector table for __trap functions.
.tbss4	Holds zero-initialized __saddr static and global variables that can be accessed via 4-bit offsets from the EP register.
.tbss5	Holds zero-initialized __saddr static and global variables that can be accessed via 5-bit offsets from the EP register.
.tbss7	Holds zero-initialized __saddr static and global variables that can be accessed via 7-bit offsets from the EP register.
.tbss8	Holds zero-initialized __saddr static and global variables that can be accessed via 8-bit offsets from the EP register.
.tdata4	Holds __saddr static and global initialized variables that can be accessed via 4-bit offsets from the EP register.
.tdata4_init	Holds initial values for .tdata4 sections when the linker directive initialize is used.
.tdata4.noinit	Holds __no_init __saddr static and global variables that can be accessed via 4-bit offsets from the EP register.
.tdata5	Holds __saddr static and global initialized variables that can be accessed via 5-bit offsets from the EP register.

Table 36: Section summary (Continued)

Section	Description
`.tdata5_init`	Holds initial values for `.tdata5` sections when the linker directive `initialize` is used.
`.tdata5.noinit`	Holds `__no_init __saddr` static and global variables that can be accessed via 5-bit offsets from the `EP` register.
`.tdata7`	Holds `__saddr` static and global initialized variables that can be accessed via 7-bit offsets from the `EP` register.
`.tdata7_init`	Holds initial values for `.tdata7` sections when the linker directive `initialize` is used.
`.tdata7.noinit`	Holds `__no_init __saddr` static and global variables that can be accessed via 7-bit offsets from the `EP` register.
`.tdata8`	Holds `__saddr` static and global initialized variables that can be accessed via 8-bit offsets from the `EP` register.
`.tdata8_init`	Holds initial values for `.tdata8` sections when the linker directive `initialize` is used.
`.tdata8.noinit`	Holds `__no_init __saddr` static and global variables that can be accessed via 8-bit offsets from the `EP` register.
`.text`	Holds the program code.
`.text.callt`	Holds `__callt` functions.
`.text.fetrap`	Holds `__fetrap` functions.
`.text.trap`	Holds `__trap` functions.
`.zbss`	Holds zero-initialized `__near` static and global variables.
`.zconst`	Holds `__near` constant data.
`.zdata`	Holds `__near` static and global initialized variables.
`.zdata_init`	Holds initial values for `.zdata` sections when the linker directive `initialize` is used.
`.zdata.noinit`	Holds `__no_init __near` static and global variables.

Table 36: Section summary (Continued)

In addition to the ELF sections used for your application, the tools use a number of other ELF sections for a variety of purposes:

- Sections starting with `.debug` generally contain debug information in the DWARF format
- Sections starting with `.iar.debug` contain supplemental debug information in an IAR format
- The section `.comment` contains the tools and command lines used for building the file

- Sections starting with `.rel` or `.rela` contain ELF relocation information
- The section `.symtab` contains the symbol table for a file
- The section `.strtab` contains the names of the symbol in the symbol table
- The section `.shstrtab` contains the names of the sections.

ROM SECTIONS FOR MULTICORE SUPPORT

These sections allow you to use the `#pragma location` directive to place code and constants in additional ROM areas. Data declared `const` must be placed in one of the `.const` sections. Which sections that are available is device-specific.

```
SECOND_ROM
SECOND_ROM.const
THIRD_ROM
THIRD_ROM.const
FOURTH_ROM
FOURTH_ROM.const
FIFTH_ROM
FIFTH_ROM.const
```

RAM SECTIONS FOR MULTICORE SUPPORT

These sections allow you to use the `#pragma location` directive to place static and global variables in additional RAM areas. Data declared `__noinit` must be placed in one of the `.noinit` sections. Which sections that are available is device-specific.

```
SECOND_RAM
SECOND_RAM.noinit
THIRD_RAM
THIRD_RAM.noinit
FOURTH_RAM
FOURTH_RAM.noinit
FIFTH_RAM
FIFTH_RAM.noinit
SELF_AREA
SELF_AREA.noinit
SELF_AREA1 – SELF_AREA7
SELF_AREA1.noinit – SELF_AREA7.noinit
LOCAL1_RAM – LOCAL7_RAM
LOCAL1_RAM.noinit – LOCAL7_RAM.noinit
RETENTION_RAM
RETENTION_RAM.noinit
```

Note: Use the section `SELF_AREA` for variables that should have a local copy in all cores. For variables that should only exist in one specific core, use the sections `SELF_AREA1–SELF_AREA7`.

Descriptions of sections and blocks

This section gives reference information about each section, where the:

- *Description* describes what type of content the section is holding and, where required, how the section is treated by the linker
- *Memory placement* describes memory placement restrictions.

For information about how to allocate sections in memory by modifying the linker configuration file, see *Placing code and data—the linker configuration file*, page 93.

CSTACK

Description

Block that holds the internal data stack for single-core G3 devices.

Memory placement

This block can be placed anywhere in the `RAM_1ST_region` memory region.

See also

Setting up stack memory, page 112.

CSTACK0

Description

Holds a core-specific stack for multicore devices.

Memory placement

This section must be placed in the `SELF_OVERLAY` memory region.

CSTACK1

Description

Holds a core-specific stack for multicore devices.

Memory placement

This section must be placed in the `SELF_OVERLAY` memory region.

CSTACK2

Description

Holds a core-specific stack for multicore devices.

Memory placement

This section must be placed in the `SELF_OVERLAY` memory region.

CSTACK3

Description

Holds a core-specific stack for multicore devices.

Memory placement — This section must be placed in the SELF_OVERLAY memory region.

CSTACK4

Description — Holds a core-specific stack for multicore devices.

Memory placement — This section must be placed in the SELF_OVERLAY memory region.

CSTACK5

Description — Holds a core-specific stack for multicore devices.

Memory placement — This section must be placed in the SELF_OVERLAY memory region.

CSTACK6

Description — Holds a core-specific stack for multicore devices.

Memory placement — This section must be placed in the SELF_OVERLAY memory region.

CSTACK7

Description — Holds a core-specific stack for multicore devices.

Memory placement — This section must be placed in the SELF_OVERLAY memory region.

.bss

Description — Holds zero-initialized __huge static and global variables.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.const

Description — Holds __huge constant data. This can include constant variables, string and aggregate literals, etc.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.data

Description — Holds `__huge` static and global initialized variables. In object files, this includes the initial values. When the linker directive `initialize` is used, a corresponding `.data_init` section is created for each `.data` section, holding the possibly compressed initial values.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.data_init

Description — Holds the possibly compressed initial values for `.data` sections. This section is created by the linker if the `initialize` linker directive is used.

Memory placement — This section is placed automatically by the linker.

See also — *Memory types*, page 68.

.data.noinit

Description — Holds static and global `__no_init __huge` variables.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

HEAP

Description — Holds the heap used for dynamically allocated data, in other words data allocated by `malloc` and `free`, and in C++, `new` and `delete`.

Memory placement — This block can be placed anywhere in memory.

See also — *Setting up heap memory*, page 112.

__iar_tls$$DATA

Description
: Holds initial values for TLS variables. This section is created by the linker if the linker option `--threaded_lib` is used.

Memory placement
: This section can be placed anywhere in the `ROM_1ST_region` memory region.

See also
: *Managing a multithreaded environment*, page 158

.iar.dynexit

Description
: Holds the table of calls to be made at exit.

Memory placement
: This section can be placed anywhere in memory.

See also
: *Setting up the atexit limit*, page 112.

.init_array

Description
: Holds pointers to routines to call for initializing one or more C++ objects with static storage duration.

Memory placement
: This section can be placed anywhere in memory.

.preinit_array

Description
: Like `.init_array`, but is used by the library to make some C++ initializations happen before the others.

Memory placement
: This section can be placed anywhere in memory.

See also
: *.init_array*, page 464.

.reset

Description
: Holds the FE exception vector table, including the reset vector table.

Memory placement
: This section must be placed at address `0x0`.

.sbss

Description — Holds zero-initialized `__brel` static and global variables.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.sbss23

Description — Holds zero-initialized `__brel23` static and global variables.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.sconst

Description — Holds `__brel` constant data. This can include constant variables, string and aggregate literals, etc.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.sconst23

Description — Holds `__brel23` constant data. This can include constant variables, string and aggregate literals, etc.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.sdata

Description — Holds `__brel` static and global initialized variables. In object files, this includes the initial values. When the linker directive `initialize by copy` is used, a corresponding `.sdata_init` section is created for each `.sdata` section, holding the possibly compressed initial values.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.sdata_init

Description — Holds the possibly compressed initial values for `.sdata` sections. This section is created by the linker if the `initialize by copy` linker directive is used.

Memory placement — This section is placed automatically by the linker.

See also — *Memory types*, page 68.

.sdata.noinit

Description — Holds static and global `__no_init __brel` variables.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.sdata23

Description — Holds `__brel23` static and global initialized variables. In object files, this includes the initial values. When the linker directive `initialize by copy` is used, a corresponding `.sdata23_init` section is created for each `.sdata23` section, holding the possibly compressed initial values.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.sdata23_init

Description — Holds the possibly compressed initial values for `.sdata23` sections. This section is created by the linker if the `initialize by copy` linker directive is used.

Memory placement — This section is placed automatically by the linker.

See also — *Memory types*, page 68.

.sdata23.noinit

Description — Holds static and global `__no_init __brel23` variables.

Memory placement — This section can be placed anywhere in memory.

See also — *Memory types*, page 68.

.table.callt

Description — Holds the vector table for `__callt` functions.

Memory placement — This section can be placed anywhere in memory.

See also — *Callt functions*, page 80.

.table.fetrap

Description — Holds the vector table for `__fetrap` functions.

Memory placement — This section can be placed anywhere in memory.

See also — *Trap functions*, page 79.

.table.syscall

Description — Holds the vector table for `__syscall` functions.

Memory placement — This section can be placed anywhere in memory.

See also — *Syscall functions*, page 81.

.table.trap

Description — Holds the vector table for `__trap` functions.

Memory placement — This section can be placed anywhere in memory.

See also — *Trap functions*, page 79.

.tbss4

Description
Holds zero-initialized `__saddr` static and global variables that can be accessed via 4-bit offsets from the `EP` register.

Memory placement
This section can be placed anywhere in memory.

See also
Memory types, page 68.

.tbss5

Description
Holds zero-initialized `__saddr` static and global variables that can be accessed via 5-bit offsets from the `EP` register.

Memory placement
This section can be placed anywhere in memory.

See also
Memory types, page 68.

.tbss7

Description
Holds zero-initialized `__saddr` static and global variables that can be accessed via 7-bit offsets from the `EP` register.

Memory placement
This section can be placed anywhere in memory.

See also
Memory types, page 68.

.tbss8

Description
Holds zero-initialized `__saddr` static and global variables that can be accessed via 8-bit offsets from the `EP` register.

Memory placement
This section can be placed anywhere in memory.

See also
Memory types, page 68.

.tdata4

Description
Holds `__saddr` static and global initialized variables that can be accessed via 4-bit offsets from the `EP` register. In object files, this includes the initial values. When the

linker directive `initialize by copy` is used, a corresponding `.tdata4_init` section is created for each `.tdata4` section, holding the possibly compressed initial values.

Memory placement

This section can be placed anywhere in memory.

See also

Memory types, page 68.

.tdata4_init

Description

Holds the possibly compressed initial values for `.tdata4` sections. This section is created by the linker if the `initialize by copy` linker directive is used.

Memory placement

This section is placed automatically by the linker.

See also

Memory types, page 68.

.tdata4.noinit

Description

Holds static and global `__no_init __saddr` variables that can be accessed via 4-bit offsets from the `EP` register.

Memory placement

This section can be placed anywhere in memory.

See also

Memory types, page 68.

.tdata5

Description

Holds `__saddr` static and global initialized variables that can be accessed via 5-bit offsets from the `EP` register. In object files, this includes the initial values. When the linker directive `initialize by copy` is used, a corresponding `.tdata5_init` section is created for each `.tdata5` section, holding the possibly compressed initial values.

Memory placement

This section can be placed anywhere in memory.

See also

Memory types, page 68.

.tdata5_init

Description

Holds the possibly compressed initial values for `.tdata5` sections. This section is created by the linker if the `initialize by copy` linker directive is used.

Memory placement

This section is placed automatically by the linker.

See also

Memory types, page 68.

.tdata5.noinit

Description

Holds static and global `__no_init __saddr` variables that can be accessed via 5-bit offsets from the `EP` register.

Memory placement

This section can be placed anywhere in memory.

See also

Memory types, page 68.

.tdata7

Description

Holds `__saddr` static and global initialized variables that can be accessed via 7-bit offsets from the `EP` register. In object files, this includes the initial values. When the linker directive `initialize by copy` is used, a corresponding `.tdata7_init` section is created for each `.tdata7` section, holding the possibly compressed initial values.

Memory placement

This section can be placed anywhere in memory.

See also

Memory types, page 68.

.tdata7_init

Description

Holds the possibly compressed initial values for `.tdata7` sections. This section is created by the linker if the `initialize by copy` linker directive is used.

Memory placement

This section is placed automatically by the linker.

See also

Memory types, page 68.

.tdata7.noinit

Description
Holds static and global `__no_init __saddr` variables that can be accessed via 7-bit offsets from the `EP` register.

Memory placement
This section can be placed anywhere in memory.

See also
Memory types, page 68.

.tdata8

Description
Holds `__saddr` static and global initialized variables that can be accessed via 8-bit offsets from the `EP` register. In object files, this includes the initial values. When the linker directive `initialize by copy` is used, a corresponding `.tdata8_init` section is created for each `.tdata8` section, holding the possibly compressed initial values.

Memory placement
This section can be placed anywhere in memory.

See also
Memory types, page 68.

.tdata8_init

Description
Holds the possibly compressed initial values for `.tdata8` sections. This section is created by the linker if the `initialize by copy` linker directive is used.

Memory placement
This section is placed automatically by the linker.

See also
Memory types, page 68.

.tdata8.noinit

Description
Holds static and global `__no_init __saddr` variables that can be accessed via 8-bit offsets from the `EP` register.

Memory placement
This section can be placed anywhere in memory.

See also
Memory types, page 68.

.text

Description
Holds program code except the code for system initialization, `__callt`, `__trap` and `__fetrap` functions.

Memory placement
This section can be placed anywhere in memory.

See also
Functions, page 77.

.text.callt

Description
Holds `__callt` functions.

Memory placement
This section must be placed immediately after the `.table.callt` section and cannot be larger than 64 Kbytes.

See also
Callt functions, page 80.

.text.fetrap

Description
Holds `__fetrap` functions.

Memory placement
This section must be placed immediately after the `.table.fetrap` section and cannot be larger than 64 Kbytes.

See also
Trap functions, page 79.

.text.trap

Description
Holds `__trap` functions.

Memory placement
This section must be placed immediately after the `.table.trap` section and cannot be larger than 64 Kbytes.

See also
Trap functions, page 79.

.zbss

Description — Holds zero-initialized `__near` static and global variables.

Memory placement — This section must be placed in near memory.

See also — *Memory types*, page 68.

.zconst

Description — Holds `__near` constant data. This can include constant variables, string and aggregate literals, etc.

Memory placement — This section must be placed in near memory.

See also — *Memory types*, page 68.

.zdata

Description — Holds `__near` static and global initialized variables. In object files, this includes the initial values. When the linker directive `initialize by copy` is used, a corresponding `.zdata_init` section is created for each `.zdata` section, holding the possibly compressed initial values.

Memory placement — This section must be placed in near memory.

See also — *Memory types*, page 68.

.zdata_init

Description — Holds the possibly compressed initial values for `.zdata` sections. This section is created by the linker if the `initialize by copy` linker directive is used.

Memory placement — This section is placed automatically by the linker.

See also — *Memory types*, page 68.

.zdata.noinit

Description	Holds static and global `__no_init __near` variables.
Memory placement	This section must be placed in near memory.
See also	*Memory types*, page 68.

The stack usage control file

- Overview
- Stack usage control directives
- Syntactic components

Before you read this chapter, see *Stack usage analysis*, page 99.

Overview

A stack usage control file consists of a sequence of directives that control stack usage analysis. You can use C ("/*...*/") and C++ ("//...") comments in these files.

The default filename extension for stack usage control files is `suc`.

Note: To comply with the Renesas ABI, the compiler generates assembler labels for C symbols like function names by prefixing an underscore. You must remember to add this extra underscore when you refer to C symbols in any of the stack usage control directives. For example, `main` must be written as `_main`.

C++ NAMES

When you specify the name of a C++ function in a stack usage control file, you must use the name exactly as used by the linker. Both the number and names of parameters, as well as the names of types must match. However, most non-significant white-space differences are accepted. In particular, you must enclose the name in quote marks because all C++ function names include non-identifier characters.

You can also use wildcards in function names. "`#*`" matches any sequence of characters, and "`#?`" matches a single character. This makes it possible to write function names that will match any instantiation of a template function.

Examples:

```
"operator new(unsigned int)"
"std::ostream::flush()"
"operator <<(std::ostream &, char const *)"
"void _Sort<#*>(#*, #*, #*)"
```

Stack usage control directives

This section gives detailed reference information about each stack usage control directive.

call graph root directive

Syntax

```
call graph root [ category ] : func-spec [, func-spec... ];
```

Parameters

category	See *category*, page 479
func-spec	See *func-spec*, page 479

Description

Specifies that the listed functions are call graph roots. You can optionally specify a call graph root category. Call graph roots are listed under their category in the *Stack Usage* chapter in the linker map file.

The linker will normally issue a warning for functions needed in the application that are not call graph roots and which do not appear to be called.

Example

```
call graph root [task]: _MyFunc10, _MyFunc11;
```

See also

call_graph_root, page 363.

exclude directive

Syntax

```
exclude func-spec [, func-spec... ];
```

Parameters

func-spec	See *func-spec*, page 479

Description

Excludes the specified functions, and call trees originating with them, from stack usage calculations.

Example

```
exclude _MyFunc5, _MyFunc6;
```

function directive

Syntax

```
[ override ] function [ category ] func-spec : stack-size
[ , call-info... ];
```

Parameters

category	See *category*, page 479
func-spec	See *func-spec*, page 479
call-info	See *call-info*, page 480
stack-size	See *stack-size*, page 480

Description

Specifies what the maximum stack usage is in a function and which other functions that are called from that function.

Normally, an error is issued if there already is stack usage information for the function, but if you start with `override`, the error will be suppressed and the information supplied in the directive will be used instead of the previous information.

Example

```
function _MyFunc1: 32,
  calls _MyFunc2,
  calls _MyFunc3, _MyFunc4: 16;

function [interrupt] _MyInterruptHandler: 44;
```

max recursion depth directive

Syntax

`max recursion depth` *`func-spec`* `:` *`size`*`;`

Parameters

func-spec	See *func-spec*, page 479
size	See *size*, page 481

Description

Specifies the maximum number of iterations through any of the cycles in the recursion nest of which the function is a member.

A recursion nest is a set of cycles in the call graph where each cycle shares at least one node with another cycle in the nest.

Stack usage analysis will base its result on the max recursion depth multiplied by the stack usage of the deepest cycle in the nest. If the nest is not entered on a point along one of the deepest cycles, no stack usage result will be calculated for such calls.

Example

```
max recursion depth _MyFunc12: 10;
```

no calls from directive

Syntax

```
no calls from module-spec to func-spec [, func-spec... ];
```

Parameters

func-spec	See *func-spec*, page 479
module-spec	See *module-spec*, page 479

Description

When you provide stack usage information for some functions in a module without stack usage information, the linker warns about functions that are referenced from the module but not listed as called. This is primarily to help avoid problems with C runtime routines, calls to which are generated by the compiler, beyond user control.

If there actually is no call to some of these functions, use the `no calls from` directive to selectively suppress the warning for the specified functions. You can also disable the warning entirely (`--diag_suppress` or **Project>Options>Linker>Diagnostics>Suppress these diagnostics**).

Example

```
no calls from [file.o] to _MyFunc13, _MyFun14;
```

possible calls directive

Syntax

```
possible calls calling-func : called-func [ , called-func... ];
```

Parameters

calling-func	See *func-spec*, page 479
called-func	See *func-spec*, page 479

Description

Specifies an exhaustive list of possible destinations for all indirect calls in one function. Use this for functions which are known to perform indirect calls and where you know exactly which functions that might be called in this particular application. Consider using the `#pragma calls` directive if the information about which functions that might be called is available when compiling.

Example

```
possible calls _MyFunc7: _MyFunc8, _MyFunc9;
```

When the function does not perform any calls, the list is empty:

```
possible calls _MyFunc8: ;
```

See also

calls, page 362.

Syntactic components

This section describes the syntactical components that can be used by the stack usage control directives.

category

Syntax

`[ name ]`

Description

A call graph root category. You can use any name you like. Categories are not case-sensitive.

Example

category examples:

```
[interrupt]
[task]
```

func-spec

Syntax

`[ ? ] name [ module-spec ]`

Description

Specifies the name of a symbol, and for module-local symbols, the name of the module it is defined in. Normally, if `func-spec` does not match a symbol in the program, a warning is emitted. Prefixing with `?` suppresses this warning.

Example

func-spec examples:

```
_xFun
_MyFun [file.o]
?"fun1(int)"
```

module-spec

Syntax

`[name [ (name) ]]`

Description

Specifies the name of a module, and optionally, in parentheses, the name of the library it belongs to. To distinguish between modules with the same name, you can specify:

- The complete path of the file ("`D:\C1\test\file.o`")
- As many path elements as are needed at the end of the path ("`test\file.o`")
- Some path elements at the start of the path, followed by `"..."`, followed by some path elements at the end ("`D:\...\file.o`").

Note: When using multi-file compilation (`--mfc`), multiple files are compiled into a single module, named after the first file.

Example

module-spec examples:

```
[file.o]
[file.o(lib.a)]
["D:\C1\test\file.o"]
```

name

Description

A name can be either an identifier or a quoted string.

The first character of an identifier must be either a letter or one of the characters "_", "$", or ".". The rest of the characters can also be digits.

A quoted string starts and ends with " and can contain any character. Two consecutive " characters can be used inside a quoted string to represent a single ".

Example

name examples:

```
_MyFun
file.o
"file-1.o"
```

call-info

Syntax

`calls` *`func-spec`* **[** `,` *`func-spec`*... **][** `:` *`stack-size`* **]**

Description

Specifies one or more called functions, and optionally, the stack size at the calls.

Example

call-info examples:

```
calls _MyFunc1 : stack 16
calls _MyFunc2, _MyFunc3, _MyFunc4
```

stack-size

Syntax

[`stack` **]** *`size`*
`(`**[** `stack` **]** `size)`
`stackname size`

Description

Specifies the size of a stack frame. A stack may not be specified more than once.

Example

stack-size examples:

```
24
CSTACK 28
```

size

Description

A decimal integer, or `0x` followed by a hexadecimal integer. Either alternative can optionally be followed by a suffix indicating a power of two (`K`=2^{10}, `M`=2^{20}, `G`=2^{30}, `T`=2^{40}, `P`=2^{50}).

Example

size examples:

```
24
0x18
2048
2K
```

IAR utilities

- The IAR Archive Tool—iarchive—creates and manipulates a library (an archive) of several ELF object files
- The IAR ELF Tool—ielftool—performs various transformations on an ELF executable image (such as fill, checksum, format conversions, etc)
- The IAR ELF Dumper—ielfdump—creates a text representation of the contents of an ELF relocatable or executable image
- The IAR ELF Object Tool—iobjmanip—is used for performing low-level manipulation of ELF object files
- The IAR Absolute Symbol Exporter—isymexport—exports absolute symbols from a ROM image file, so that they can be used when you link an add-on application.
- Descriptions of options—detailed reference information about each command line option available for the different utilities.

The IAR Archive Tool—iarchive

The IAR Archive Tool, `iarchive`, can create a library (an archive) file from several ELF object files. You can also use `iarchive` to manipulate ELF libraries.

A library file contains several relocatable ELF object modules, each of which can be independently used by a linker. In contrast with object modules specified directly to the linker, each module in a library is only included if it is needed.

For information about how to build a library in the IDE, see the *IDE Project Management and Building Guide for RH850.*

INVOCATION SYNTAX

The invocation syntax for the archive builder is:

```
iarchive parameters
```

Parameters

The parameters are:

Parameter	Description
command	Command line options that define an operation to be performed. Such an option must be specified before the name of the library file.
libraryfile	The library file to be operated on.
objectfile1 ... objectfileN	The object file(s) that the specified command operates on.
options	Command line options that define actions to be performed. These options can be placed anywhere on the command line.

Table 37: iarchive parameters

Examples

This example creates a library file called `mylibrary.a` from the source object files `module1.o`, `module.2.o`, and `module3.o`:

```
iarchive mylibrary.a module1.o module2.o module3.o.
```

This example lists the contents of `mylibrary.a`:

```
iarchive --toc mylibrary.a
```

This example replaces `module3.o` in the library with the content in the `module3.o` file and appends `module4.o` to `mylibrary.a`:

```
iarchive --replace mylibrary.a module3.o module4.o
```

SUMMARY OF IARCHIVE COMMANDS

This table summarizes the `iarchive` commands:

Command line option	Description
`--create`	Creates a library that contains the listed object files.
`--delete, -d`	Deletes the listed object files from the library.
`--extract, -x`	Extracts the listed object files from the library.
`--replace, -r`	Replaces or appends the listed object files to the library.
`--symbols`	Lists all symbols defined by files in the library.
`--toc, -t`	Lists all files in the library.

Table 38: iarchive commands summary

For more information, see *Descriptions of options*, page 500.

SUMMARY OF IARCHIVE OPTIONS

This table summarizes the `iarchive` command line options:

Command line option	Description
`-f`	Extends the command line.
`--f`	Extends the command line, optionally with a dependency.
`--no_bom`	Omits the byte order mark from UTF-8 output files.
`--output, -o`	Specifies the library file.
`--text_out`	Specifies the encoding for text output files.
`--utf8_text_in`	Uses the UTF-8 encoding for text input files.
`--verbose, -V`	Reports all performed operations.
`--version`	Sends tool output to the console and then exits.
`--vtoc`	Produces a verbose list of files in the library.

Table 39: iarchive options summary

For more information, see *Descriptions of options*, page 500.

DIAGNOSTIC MESSAGES

This section lists the messages produced by `iarchive`:

La001: could not open file *filename*

`iarchive` failed to open an object file.

La002: illegal path *pathname*

The path *`pathname`* is not a valid path.

La006: too many parameters to *cmd* command

A list of object modules was specified as parameters to a command that only accepts a single library file.

La007: too few parameters to *cmd* command

A command that takes a list of object modules was issued without the expected modules.

La008: *lib* is not a library file

The library file did not pass a basic syntax check. Most likely the file is not the intended library file.

La009: *lib* has no symbol table

The library file does not contain the expected symbol information. The reason might be that the file is not the intended library file, or that it does not contain any ELF object modules.

La010: no library parameter given

The tool could not identify which library file to operate on. The reason might be that a library file has not been specified.

La011: file *file* already exists

The file could not be created because a file with the same name already exists.

La013: file confusions, *lib* given as both library and object

The library file was also mentioned in the list of object modules.

La014: module *module* not present in archive *lib*

The specified object module could not be found in the archive.

La015: internal error

The invocation triggered an unexpected error in `iarchive`.

Ms003: could not open file *filename* for writing

`iarchive` failed to open the archive file for writing. Make sure that it is not write protected.

Ms004: problem writing to file *filename*

An error occurred while writing to file *`filename`*. A possible reason for this is that the volume is full.

Ms005: problem closing file *filename*

An error occurred while closing the file *`filename`*.

The IAR ELF Tool—ielftool

The IAR ELF Tool, `ielftool`, can generate a checksum on specific ranges of memories. This checksum can be compared with a checksum calculated on your application.

The source code for `ielftool` and a Microsoft Visual Studio template project are available in the `rh850\src\elfutils` directory. If you have specific requirements for how the checksum should be generated or requirements for format conversion, you can modify the source code accordingly.

INVOCATION SYNTAX

The invocation syntax for the IAR ELF Tool is:

```
ielftool [options] inputfile outputfile [options]
```

The `ielftool` tool will first process all the fill options, then it will process all the checksum options (from left to right).

Parameters

The parameters are:

Parameter	Description
inputfile	An absolute ELF executable image produced by the ILINK linker.
options	Any of the available command line options, see *Summary of ielftool options*, page 487.
outputfile	An absolute ELF executable image, or if one of the relevant command line options is specified, an image file in another format.

Table 40: ielftool parameters

See also *Rules for specifying a filename or directory as parameters*, page 252.

Example

This example fills a memory range with `0xFF` and then calculates a checksum on the same range:

```
ielftool my_input.out my_output.out --fill 0xFF;0-0xFF
           --checksum __checksum:4,crc32;0-0xFF
```

SUMMARY OF IELFTOOL OPTIONS

This table summarizes the `ielftool` command line options:

Command line option	Description
`--bin`	Sets the format of the output file to raw binary.
`--bin-multi`	Produces output to multiple raw binary files.
`--checksum`	Generates a checksum.
`--fill`	Specifies fill requirements.

Table 41: ielftool options summary

Command line option	Description
`--front_headers`	Outputs headers in the beginning of the file.
`--ihex`	Sets the format of the output file to 32-bit linear Intel Extended hex.
`--ihex-len`	Sets the number of data bytes in Intel Hex records.
`--offset`	Adds (or subtracts) an offset to all addresses in the generated output file.
`--parity`	Generates parity bits.
`--self_reloc`	Not for general use.
`--silent`	Sets silent operation.
`--simple`	Sets the format of the output file to Simple-code.
`--simple-ne`	As `--simple`, but without an entry record.
`--srec`	Sets the format of the output file to Motorola S-records.
`--srec-len`	Sets the number of data bytes in each S-record.
`--srec-s3only`	Restricts the S-record output to contain only a subset of records.
`--strip`	Removes debug information.
`--titxt`	Sets the format of the output file to Texas Instruments TI-TXT.
`--verbose, -V`	Prints all performed operations.
`--version`	Sends tool output to the console and then exits.

Table 41: ielftool options summary (Continued)

For more information, see *Descriptions of options*, page 500.

SPECIFYING IELFTOOL ADDRESS RANGES

At the most basic level, an address range for `ielftool` consists of two hexidecimal numbers—`0x8000-0x87FF`—which includes both `0x8000` and `0x87FF`.

You can specify ELF symbols that are present in the processed ELF file as a start or end address using `__checksum_begin-__checksum_end`. This range begins on the byte that has the address value of the `__checksum_begin` symbol and ends (inclusive) on the byte that has the address value of the `__checksum_end` symbol. Symbol values of `0x40` and `0x3FD` would equate to specifying `0x40-0x3FD`.

You can add offsets to symbolic values using `__start+3-__end+0x10`. The calculation is done in modulo 32-bits, therefore adding `0xFFFFFFFF` is equivalent to subtracting 1.

You can specify blocks from an `.icf` file that are present in the processed ELF file using `{BLOCKNAME}`. A block started on `0x400` and ending (inclusively) on `0x535`, would equate to specifying `0x400-0x535`.

You can combine several address ranges, as long as they do not overlap, separated by `0x800-1FFF {FARCODE_BLOCK}`.

You can specify `__FLASH_BASE-__FLASH_END` as a legal range (as long as there is no overlap).

The IAR ELF Dumper—ielfdump

The IAR ELF Dumper for RH850, `ielfdumprh850`, can be used for creating a text representation of the contents of a relocatable or absolute ELF file.

`ielfdumprh850` can be used in one of three ways:

- To produce a listing of the general properties of the input file and the ELF segments and ELF sections it contains. This is the default behavior when no command line options are used.
- To also include a textual representation of the contents of each ELF section in the input file. To specify this behavior, use the command line option `--all`.
- To produce a textual representation of selected ELF sections from the input file. To specify this behavior, use the command line option `--section`.

INVOCATION SYNTAX

The invocation syntax for `ielfdumprh850` is:

`ielfdumprh850` *`input_file`* `[`*`output_file`*`]`

Note: `ielfdumprh850` is a command line tool which is not primarily intended to be used in the IDE.

Parameters

The parameters are:

Parameter	Description
input_file	An ELF relocatable or executable file to use as input.
output_file	A file or directory where the output is emitted. If absent and no `--output` option is specified, output is directed to the console.

Table 42: ielfdumprh850 parameters

See also *Rules for specifying a filename or directory as parameters*, page 252.

SUMMARY OF IELFDUMP OPTIONS

This table summarizes the `ielfdumprh850` command line options:

Command line option	Description
`--a`	Generates output for all sections except string table sections.
`--all`	Generates output for all input sections regardless of their names or numbers.
`--code`	Dumps all sections that contain executable code.
`--disasm_data`	Dumps data sections as code sections.
`-f`	Extends the command line.
`--f`	Extends the command line, optionally with a dependency.
`--no_bom`	Omits the Byte Order Mark from UTF-8 output files.
`--no_header`	Suppresses production of a list header in the output.
`--no_rel_section`	Suppresses dumping of `.rel`/`.rela` sections.
`--no_strtab`	Suppresses dumping of string table sections.
`--no_utf8_in`	Do not assume UTF-8 for non-IAR ELF files.
`--output, -o`	Specifies an output file.
`--range`	Disassembles only addresses in the specified range.
`--raw`	Uses the generic hexadecimal/ASCII output format for the contents of any selected section, instead of any dedicated output format for that section.
`--section, -s`	Generates output for selected input sections.
`--segment, -g`	Generates output for segments with specified numbers.
`--source`	Includes source with disassembled code in executable files.
`--text_out`	Specifies the encoding for text output files.
`--use_full_std_template_names`	Uses full short full names for some Standard C++ templates.
`--utf8_text_in`	Uses the UTF-8 encoding for text input files.
`--version`	Sends tool output to the console and then exits.

Table 43: ielfdumprh850 options summary

For more information, see *Descriptions of options*, page 500.

The IAR ELF Object Tool—iobjmanip

Use the IAR ELF Object Tool, `iobjmanip`, to perform low-level manipulation of ELF object files.

INVOCATION SYNTAX

The invocation syntax for the IAR ELF Object Tool is:

```
iobjmanip options inputfile outputfile
```

Parameters

The parameters are:

Parameter	Description
options	Command line options that define actions to be performed. These options can be placed anywhere on the command line. At least one of the options must be specified.
inputfile	A relocatable ELF object file.
outputfile	A relocatable ELF object file with all the requested operations applied.

Table 44: iobjmanip parameters

See also *Rules for specifying a filename or directory as parameters*, page 252.

Examples

This example renames the section `.example` in `input.o` to `.example2` and stores the result in `output.o`:

```
iobjmanip --rename_section .example=.example2 input.o output.o
```

SUMMARY OF IOBJMANIP OPTIONS

This table summarizes the `iobjmanip` options:

Command line option	Description
`-f`	Extends the command line.
`--f`	Extends the command line, optionally with a dependency.
`--no_bom`	Omits the Byte Order Mark from UTF-8 output files.
`--remove_file_path`	Removes path information from the file symbol.
`--remove_section`	Removes one or more section.
`--rename_section`	Renames a section.
`--rename_symbol`	Renames a symbol.
`--strip`	Removes debug information.
`--text_out`	Specifies the encoding for text output files.
`--utf8_text_in`	Uses the UTF-8 encoding for text input files.

Table 45: iobjmanip options summary

Command line option	Description
`--version`	Sends tool output to the console and then exits.

Table 45: iobjmanip options summary (Continued)

For more information, see *Descriptions of options*, page 500.

DIAGNOSTIC MESSAGES

This section lists the messages produced by `iobjmanip`:

Lm001: No operation given

None of the command line parameters specified an operation to perform.

Lm002: Expected *nr* parameters but got *nr*

Too few or too many parameters. Check invocation syntax for `iobjmanip` and for the used command line options.

Lm003: Invalid section/symbol renaming pattern *pattern*

The pattern does not define a valid renaming operation.

Lm004: Could not open file *filename*

`iobjmanip` failed to open the input file.

Lm005: ELF format error *msg*

The input file is not a valid ELF object file.

Lm006: Unsupported section type *nr*

The object file contains a section that `iobjmanip` cannot handle. This section will be ignored when generating the output file.

Lm007: Unknown section type *nr*

`iobjmanip` encountered an unrecognized section. `iobjmanip` will try to copy the content as is.

Lm008: Symbol *symbol* has unsupported format

`iobjmanip` encountered a symbol that cannot be handled. `iobjmanip` will ignore this symbol when generating the output file.

Lm009: Group type *nr* not supported

`iobjmanip` only supports groups of type `GRP_COMDAT`. If any other group type is encountered, the result is undefined.

Lm010: Unsupported ELF feature in *file*: *msg*

The input file uses a feature that `iobjmanip` does not support.

Lm011: Unsupported ELF file type

The input file is not a relocatable object file.

Lm012: Ambiguous rename for section/symbol *name* (*alt1* and *alt2*)

An ambiguity was detected while renaming a section or symbol. One of the alternatives will be used.

Lm013: Section *name* removed due to transitive dependency on *name*

A section was removed as it depends on an explicitly removed section.

Lm014: File has no section with index *nr*

A section index, used as a parameter to `--remove_section` or `--rename_section`, did not refer to a section in the input file.

Ms003: could not open file *filename* for writing

`iobjmanip` failed to open the output file for writing. Make sure that it is not write protected.

Ms004: problem writing to file *filename*

An error occurred while writing to file *`filename`*. A possible reason for this is that the volume is full.

Ms005: problem closing file *filename*

An error occurred while closing the file *`filename`*.

The IAR Absolute Symbol Exporter—isymexport

The IAR Absolute Symbol Exporter, `isymexport`, can export absolute symbols from a ROM image file, so that they can be used when you link an add-on application.

To keep symbols from your symbols file in your final application, the symbols must be referred to, either from your source code or by using the linker option `--keep`.

INVOCATION SYNTAX

The invocation syntax for the IAR Absolute Symbol Exporter is:

```
isymexport [options] inputfile outputfile
```

Parameters

The parameters are:

Parameter	Description
inputfile	A ROM image in the form of an executable ELF file (output from linking).
options	Any of the available command line options, see *Summary of isymexport options*, page 494.
outputfile	A relocatable ELF file that can be used as input to linking, and which contains all or a selection of the absolute symbols in the input file. The output file contains only the symbols, not the actual code or data sections. A steering file can be used for controlling which symbols are included, and if desired, for also renaming some of the symbols.

Table 46: isymexport parameters

See also *Rules for specifying a filename or directory as parameters*, page 252.

In the IDE, to add the export of library symbols, choose **Project>Options>Build Actions** and specify your command line in the **Post-build command line** text field, for example:

```
$TOOLKIT_DIR$\bin\isymexport.exe "$TARGET_PATH$"
"$PROJ_DIR$\const_lib.symbols"
```

SUMMARY OF ISYMEXPORT OPTIONS

This table summarizes the `isymexport` command line options:

Command line option	Description
`--edit`	Specifies a steering file.
`--export_locals`	Exports local symbols.
`-f`	Extends the command line.
`--f`	Extends the command line, optionally with a dependency.

Table 47: isymexport options summary

Command line option	Description
`--generate_vfe_header`	Declares that the image does not contain any virtual function calls to potentially discarded functions.
`--no_bom`	Omits the Byte Order Mark from UTF-8 output files.
`--ram_reserve_ranges`	Generates symbols for the areas in RAM that the image uses.
`--reserve_ranges`	Generates symbols to reserve the areas in ROM and RAM that the image uses.
`--show_entry_as`	Exports the entry point of the application with the given name.
`--text_out`	Specifies the encoding for text output files.
`--utf8_text_in`	Uses the UTF-8 encoding for text input files.
`--version`	Sends tool output to the console and then exits.

Table 47: isymexport options summary (Continued)

For more information, see *Descriptions of options*, page 500.

STEERING FILES

A steering file can be used for controlling which symbols are included, and if desired, for also renaming some of the symbols. In the file, you can use `show` and `hide` directives to select which public symbols from the input file that are to be included in the output file. `rename` directives can be used for changing the names of symbols in the input file.

When you use a steering file, only actively exported symbols will be available in the output file. Therefore, a steering file without `show` directives will generate an output file without symbols.

Syntax

The following syntax rules apply:

- Each directive is specified on a separate line.
- C comments (`/*...*/`) and C++ comments (`//...`) can be used.
- Patterns can contain wildcard characters that match more than one possible character in a symbol name.
- The `*` character matches any sequence of zero or more characters in a symbol name.
- The `?` character matches any single character in a symbol name.

Example

```
rename xxx_* as YYY_* /*Change symbol prefix from xxx_ to YYY_ */
show YYY_*            /* Export all symbols from YYY package */
hide *_internal       /* But do not export internal symbols */
show zzz?             /* Export zzza, but not zzzaaa */
hide zzzx             /* But do not export zzzx */
```

Hide directive

Syntax

`hide` *`pattern`*

Parameters

`pattern`	A pattern to match against a symbol name.

Description

A symbol with a name that matches the pattern will not be included in the output file unless this is overridden by a later `show` directive.

Example

```
/* Do not include public symbols ending in _sys. */
hide *_sys
```

Rename directive

Syntax

`rename` *`pattern1`* `as` *`pattern2`*

Parameters

`pattern1`	A pattern used for finding symbols to be renamed. The pattern can contain no more than one `*` or `?` wildcard character.
`pattern2`	A pattern used for the new name for a symbol. If the pattern contains a wildcard character, it must be of the same kind as in *`pattern1`*.

Description

Use this directive to rename symbols from the output file to the input file. No exported symbol is allowed to match more than one `rename` pattern.

`rename` directives can be placed anywhere in the steering file, but they are executed before any `show` and `hide` directives. Therefore, if a symbol will be renamed, all `show` and `hide` directives in the steering file must refer to the new name.

If the name of a symbol matches a *`pattern1`* pattern that contains no wildcard characters, the symbol will be renamed *`pattern2`* in the output file.

If the name of a symbol matches a *pattern1* pattern that contains a wildcard character, the symbol will be renamed *pattern2* in the output file, with part of the name matching the wildcard character preserved.

Example

```
/* xxx_start will be renamed Y_start_X in the output file,
   xxx_stop will be renamed Y_stop_X in the output file. */
rename xxx_* as Y_*_X
```

Show directive

Syntax

`show pattern`

Parameters

pattern	A pattern to match against a symbol name.

Description

A symbol with a name that matches the pattern will be included in the output file unless this is overridden by a later `hide` directive.

Example

```
/* Include all public symbols ending in _pub. */
show *_pub
```

Show-root directive

Syntax

`show-root pattern`

Parameters

pattern	A pattern to match against a symbol name.

Description

A symbol with a name that matches the pattern will be included in the output file, marked as `root`, unless this is overridden by a later `hide` directive.

When linking with the module produced by `isymexport`, the symbol will be included in the final executable file, even if no references to the symbol are present in the build.

Example

```
/* Export myVar making sure that it is included when linking */
show-root myVar
```

Show-weak directive

Syntax

```
show-weak pattern
```

Parameters

pattern	A pattern to match against a symbol name.

Description

A symbol with a name that matches the pattern will be included in the output file as a weak symbol unless this is overridden by a later `hide` directive.

When linking, no error will be reported if the new code contains a definition for a symbol with the same name as the exported symbol.

Note: Any internal references in the `isymexport` input file are already resolved and cannot be affected by the presence of definitions in the new code.

Example

```
/* Export myFunc as a weak definition */
show-weak myFunc
```

DIAGNOSTIC MESSAGES

This section lists the messages produced by `isymexport`:

Es001: could not open file *filename*

`isymexport` failed to open the specified file.

Es002: illegal path *pathname*

The path *`pathname`* is not a valid path.

Es003: format error: *message*

A problem occurred while reading the input file.

Es004: no input file

No input file was specified.

Es005: no output file

An input file, but no output file was specified.

Es006: too many input files

More than two files were specified.

Es007: input file is not an ELF executable

The input file is not an ELF executable file.

Es008: unknown directive: *directive*

The specified directive in the steering file is not recognized.

Es009: unexpected end of file

The steering file ended when more input was required.

Es010: unexpected end of line

A line in the steering file ended before the directive was complete.

Es011: unexpected text after end of directive

There is more text on the same line after the end of a steering file directive.

Es012: expected *text*

The specified text was not present in the steering file, but must be present for the directive to be correct.

Es013: pattern can contain at most one * or ?

Each pattern in the current directive can contain at most one `*` or one `?` wildcard character.

Es014: rename patterns have different wildcards

Both patterns in the current directive must contain exactly the same kind of wildcard. That is, both must either contain:

- No wildcards
- Exactly one `*`
- Exactly one `?`

This error occurs if the patterns are not the same in this regard.

Es015: ambiguous pattern match: *symbol* matches more than one rename pattern

A symbol in the input file matches more than one `rename` pattern.

Es016: the entry point symbol is already exported

The option `--show_entry_as` was used with a name that already exists in the input file.

Descriptions of options

This section gives detailed reference information about each command line option available for the different utilities.

--a

Syntax `--a`

For use with `ielfdumprh850`

Description Use this option as a shortcut for `--all --no_strtab`.

This option is not available in the IDE.

--all

Syntax `--all`

For use with `ielfdumprh850`

Description Use this option to include the contents of all ELF sections in the output, in addition to the general properties of the input file. Sections are output in index order, except that each relocation section is output immediately after the section it holds relocations for.

By default, no section contents are included in the output.

This option is not available in the IDE.

--bin

Syntax `--bin[=range]`

Parameters

range	The address range content to include in the output file. The address range can be specified using literals, or by using symbols present in the ELF file. Examples: `"0x8000-0x8FFF"`, `"START-END"`

For use with `ielftool`

Description

Sets the format of the output file to raw binary, a binary format that includes only the raw bytes, with no address information. If no range is specified, the output file will include all the bytes from the lowest address for which there is content in the ELF file to the highest address for which there is content. If a range is specified, only bytes from that range are included. Note that in both cases, any gaps for which there is no content will be generated as zeros.

To set related options, choose:

Project>Options>Output converter

--bin-multi

Syntax `--bin-multi[=range[;range...]]`

Parameters

range	An address range to produce an output file for. An address range can be specified using literals, or by using symbols present in the ELF file. Examples: `"0x8000-0x8FFF"`, `"START-END"`

For use with `ielftool`

Description

Use this option to produce one or more raw binary output files. If no ranges are specified, a raw binary output file is generated for each range for which there is content in the ELF file. If ranges are specified, a raw binary output file is generated for each range specified. In each case, the name of each output file will include the start address of its range. For example, if the output file is specified as `out.bin` and the ranges `0x0-0x1F` and `0x8000-0x8147` are output, there will be two files, named `out-0x0.bin` and `out-0x8000.bin`.

This option is not available in the IDE.

--checksum

Syntax

```
--checksum {symbol[{+|-}offset]|address}:size,
algorithm[:[1|2][a|m|z][L|W][x][r][R][o][i|p]]
[,start];range[;range...]
```

Parameters

symbol	The name of the symbol where the checksum value should be stored. Note that it must exist in the symbol table in the input ELF file.
offset	The offset will be added (or subtracted if a negative offset (`-`) is specified) to the symbol. Address expressions using `+` and `-` are supported in a limited fashion. For example: `(start+7)-(end-2)`.
address	The absolute address where the checksum value should be stored.
size	The number of bytes in the checksum—`1`, `2`, or `4`. The number cannot be larger than the size of the checksum symbol.
algorithm	The checksum algorithm used. Choose between: *sum*, a byte-wise calculated arithmetic sum. The result is truncated to 8 bits. *sum8wide*, a byte-wise calculated arithmetic sum. The result is truncated to the size of the symbol. *sum32*, a word-wise (32 bits) calculated arithmetic sum. *crc16*, CRC16 (generating polynomial `0x1021`); used by default. *crc32*, CRC32 (generating polynomial `0x04C11DB7`). *crc64iso*, CRC64iso (generating polynomial `0x1B`). *crc64ecma*, CRC64ECMA (generating polynomial `0x42F0E1EBA9EA3693`). *crc=n*, CRC with a generating polynomial of *n*.

`1|2`	If specified, choose between: `1`, specifies one's complement. `2`, specifies two's complement.
`a|m|z`	Reverses the order of the bits for the checksum. Choose between: `a`, reverses the input bytes (but nothing else). `m`, reverses the input bytes and the final checksum. `z`, reverses the final checksum (but nothing else). Note that using `a` and `z` in combination has the same effect as `m`.
`L|W`	Specifies the size of the unit for which a checksum should be calculated. Choose between: `L`, calculates a checksum on 32 bits in every iteration `W`, calculates a checksum on 16 bits in every iteration. If you do not specify a unit size, 8 bits will be used by default. The input byte sequence will processed as: • `8-bit checksum unit size —byte0, byte1, byte2, byte3, etc.` • 16-bit checksum unit size—byte1, byte0, byte3, byte2, etc. • 32-bit checksum unit size—byte3, byte2, byte1, byte0, byte7, byte6, byte5, byte4, etc. **Note:** The checksum unit size only affects the order in which the input byte sequence is processed. It does not affect the size of the checksum symbol, the polynomial, the initial value, the width of the processor's address bus, etc. Most software CRC implementations use a checksum unit size of 1 byte (8 bits). The `L` and `W` parameters are almost exclusively used when a software CRC implementation has to match the checksum computed by the hardware CRC implementation. If you are not trying to cooperate with a hardware CRC implementation, the `L` and `W` parameter will simply compute a different checksum, because it processes the input byte sequence in a different order.
`x`	Reverses the byte order of the checksum. This only affects the checksum value.

`r`	Reverses the byte order of the input data. This has no effect unless the number of bits per iteration has been set using the `L` or `W` parameters.
`R`	Traverses the checksum range(s) in reverse order. If the range is, for example, `0x100–0xFFF;0x2000–0x2FFF`, the checksum calculation will normally start on `0x100` and then calculate every byte up to and including `0xFFF`, followed by calculating the byte on `0x2000` and continue to `0x2FFF`. Using the `R` parameter, the calculation instead starts on `0x2FFF` and continues by calculating every byte down to `0x2000`, then from `0xFFF` down to and including `0x100`.
`o`	Outputs the Rocksoft model specification for the checksum.
`i|p`	Use either `i` or `p`, if the *`start`* value is bigger than `0`. Choose between: `i`, initializes the checksum value with the start value. `p`, prefixes the input data with a word of size *`size`* that contains the *`start`* value.
`start`	By default, the initial value of the checksum is `0`. If necessary, use *`start`* to supply a different initial value. If not `0`, then either `i` or `p` must be specified.

range	*range* is one or more memory ranges for which the checksum will be calculated. Hexadecimal and decimal notation is allowed, for example, `0x8002-0x8FFF`. The memory range(s) can also be expressed as:

- Symbols that are present in ELF file can be used in the range description, for example, `__checksum_begin-__checksum_end`.
- One or more block names where each block is placed inside a pair of curly braces,`{}`, like `{MY_BLOCK}`. A block that is used in this manner must be specified in the linker configuration file and must contain only read-only content. See *define block directive*, page 433.

It is typically advisable to use symbols or blocks if the memory range can change. If you use explicit addresses, for example, `0x8000-0x8347`, and the code then changes, you need to update the end address to the new value. If you instead use `{CODE}` or a symbol located at the end of the code, you do not need to update the `--checksum` command.

For use with

`ielftool`

Description

Use this option to calculate a checksum with the specified algorithm for the specified ranges. If you have an external definition for the checksum—for example, a hardware CRC implementation—use the appropriate parameters to the `--checksum` option to match the external design. In this case, learn more about that design in the hardware documentation. The checksum will then replace the original value in *symbol*. A new absolute symbol will be generated, with the *symbol* name suffixed with `_value` containing the calculated checksum. This symbol can be used for accessing the checksum value later when needed, for example, during debugging.

If the `--checksum` option is used more than once on the command line, the options are evaluated from left to right. If a checksum is calculated for a *symbol* that is specified in a later evaluated `--checksum` option, an error is issued.

Example

This example shows how to use the crc16 algorithm with the start value `0` over the address range `0x8000-0x8FFF`:

```
ielftool --checksum=__checksum:2,crc16;0x8000-0x8FFF
sourceFile.out destinationFile.out
```

The input data i read from `sourceFile.out`, and the resulting checksum value of size 2 bytes will be stored at the symbol `__checksum`. The modified ELF file is saved as `destinationFile.out` leaving `sourceFile.out` untouched.

In the next example, a symbol is used for specifying the start of the range:

```
ielftool --checksum=__checksum:2,crc16;__checksum_begin-0x8FFF
sourceFile.out destinationFile.out
```

If `BLOCK1` occupies `0x4000-0x4337` and `BLOCK2` occupies `0x8000-0x87FF`, this example will compute the checksum for the bytes on `0x4000` to `0x4337` and from `0x8000` to `0x87FF`:

```
ielftool --checksum __checksum:2,crc16;{BLOCK1};{BLOCK2}
BlxTest.out BlxTest2.out
```

See also

Checksum calculation for verifying image integrity, page 209

Specifying ielftool address ranges, page 488

To set related options, choose:

Project>Options>Linker>Checksum

--code

Syntax

```
--code
```

For use with

`ielfdumprh850`

Description

Use this option to dump all sections that contain executable code—sections with the ELF section attribute `SHF_EXECINSTR`.

This option is not available in the IDE.

--create

Syntax

--create *libraryfile objectfile1 ... objectfileN*

Parameters

libraryfile	The library file that the command operates on. See *Rules for specifying a filename or directory as parameters*, page 252.
objectfile1 ... objectfileN	The object file(s) to build the library from.

For use with

`iarchive`

Description

Use this command to build a new library from a set of object files (modules). The object files are added to the library in the exact order that they are specified on the command line.

If no command is specified on the command line, `--create` is used by default.

This option is not available in the IDE.

--delete, -d

Syntax

```
--delete libraryfile objectfile1 ... objectfileN
-d libraryfile objectfile1 ... objectfileN
```

Parameters

libraryfile	The library file that the command operates on. See *Rules for specifying a filename or directory as parameters*, page 252.
objectfile1 ... objectfileN	The object file(s) that the command operates on.

For use with

`iarchive`

Description

Use this command to remove object files (modules) from an existing library. All object files that are specified on the command line will be removed from the library.

This option is not available in the IDE.

--disasm_data

Syntax

`--disasm_data`

For use with

`ielfdumprh850`

Description

Use this command to instruct the dumper to dump data sections as if they were code sections.

This option is not available in the IDE.

--edit

Syntax

`--edit` *`steering_file`*

For use with

`isymexport`

Description

Use this option to specify a steering file for controlling which symbols are included in the `isymexport` output file, and if desired, also for renaming some of the symbols.

See also

Steering files, page 495.

This option is not available in the IDE.

--export_locals

Syntax

`--export_locals [=`*`symbol_prefix`*`]`

Parameters

`symbol_prefix`	A custom prefix to the names of exported symbols that replaces the default prefix `LOCAL`.

For use with

`isymexport`

Description

Use this option to export local symbols from a ROM image file, in addition to absolute symbols. The default name of the exported symbol is `LOCAL_`*`filename_symbolname`*. Use the optional parameter *`symbol_prefix`* to replace `LOCAL` with your custom prefix.

Example

When exported from the ROM image file, the symbol `symb` in the source file `myFile.c` becomes `LOCAL_myFile_c_symb`.

This option is not available in the IDE.

--extract, -x

Syntax

```
--extract libraryfile [objectfile1 ... objectfileN]
-x libraryfile [objectfile1 ... objectfileN]
```

Parameters

`libraryfile`	The library file that the command operates on. See *Rules for specifying a filename or directory as parameters*, page 252.

`objectfile1 ... objectfileN` The object file(s) that the command operates on.

For use with `iarchive`

Description Use this command to extract object files (modules) from an existing library. If a list of object files is specified, only these files are extracted. If a list of object files is not specified, all object files in the library are extracted.

This option is not available in the IDE.

-f

Syntax `-f filename`

Parameters See *Rules for specifying a filename or directory as parameters*, page 252.

For use with `iarchive`, `ielfdumprh850`, `iobjmanip`, and `isymexport`.

Description Use this option to make the tool read command line options from the named file, with the default filename extension `xcl`.

In the command file, you format the items exactly as if they were on the command line itself, except that you can use multiple lines, because the newline character acts just as a space or tab character.

Both C and C++ style comments are allowed in the file. Double quotes behave in the same way as in the Microsoft Windows command line environment.

This option is not available in the IDE.

--f

Syntax `--f filename`

Parameters See *Rules for specifying a filename or directory as parameters*, page 252.

For use with `iarchive`, `ielfdumprh850`, `iobjmanip`, and `isymexport`.

Description Use this option to make the tool read command line options from the named file, with the default filename extension `xcl`.

In the command file, you format the items exactly as if they were on the command line itself, except that you may use multiple lines, because the newline character acts just as a space or tab character.

Both C and C++ style comments are allowed in the file. Double quotes behave in the same way as in the Microsoft Windows command line environment.

If you also specify `--dependencies` on the command line for the tool, extended command line files specified using `--f` will generate a dependency, but those specified using `-f` will not generate a dependency.

See also

-f, page 509.

This option is not available in the IDE.

--fill

Syntax

```
--fill [v;]pattern;range[;range...]
```

Parameters

`v`	Generates virtual fill for the fill command. Virtual fill is filler bytes that are included in checksumming, but that are not included in the output file. The primary use for this is certain types of hardware where bytes that are not specified by the image have a known value—typically, `0xFF` or `0x0`.
`pattern`	A hexadecimal string with the `0x` prefix, for example, `0xEF`, interpreted as a sequence of bytes, where each pair of digits corresponds to one byte, for example `0x123456`, for the sequence of bytes `0x12`, `0x34`, and `0x56`. This sequence is repeated over the fill area. If the length of the fill pattern is greater than `1` byte, it is repeated as if it started at address 0.
`range`	Specifies the address range for the fill. Hexadecimal and decimal notation is allowed, for example, `0x8002-0x8FFF`. Note that each address must be 4-byte aligned. Symbols that are present in the ELF file can be used in the range description, for example, `__checksum_begin-__checksum_end`.

For use with

`ielftool`

Description

Use this option to fill all gaps in one or more ranges with a pattern, which can be either an expression or a hexadecimal string. The contents will be calculated as if the fill pattern was repeatedly filled from the start address until the end address is passed, and then the real contents will overwrite that pattern.

If the `--fill` option is used more than once on the command line, the fill ranges cannot overlap each other.

To set related options, choose:

Project>Options>Linker>Checksum

--front_headers

Syntax

`--front_headers`

For use with

`ielftool`

Description

Use this option to output ELF program and section headers in the beginning of the file, instead of at the end.

This option is not available in the IDE.

--generate_vfe_header

Syntax

`--generate_vfe_header`

For use with

`isymexport`

Description

Use this option to declare that the image does not contain any virtual function calls to potentially discarded functions.

When the linker performs virtual function elimination, it discards virtual functions that appear not to be needed. For the optimization to be applied correctly, there must be no virtual function calls in the image that affect the functions that are discarded.

See also

Virtual function elimination, page 121.

To set this options, use:

Project>Options>Linker>Extra Options

--ihex

Syntax `--ihex`

For use with `ielftool`

Description Sets the format of the output file to 32-bit linear Intel Extended hex, a hexadecimal text format defined by Intel.

To set related options, choose:

Project>Options>Linker>Output converter

--ihex-len

Syntax `--ihex-len=`*`length`*

Parameters

length	The number of data bytes in the record.

For use with `ielftool`

Description Sets the maximum number of data bytes in an Intel Hex record. This option can only be used together with the `--ihex` option. By default, the number of data bytes in an Intel Hex record is 16.

This option is not available in the IDE.

--no_bom

Syntax `--no_bom`

For use with `iarchive`, `ielfdumprh850`, `iobjmanip`, and `isymexport`

Description Use this option to omit the Byte Order Mark (BOM) when generating a UTF-8 output file.

See also --*text_out*, page 525 and *Text encodings*, page 246

This option is not available in the IDE.

--no_header

Syntax `--no_header`

For use with `ielfdumprh850`

Description By default, a standard list header is added before the actual file content. Use this option to suppress output of the list header.

This option is not available in the IDE.

--no_rel_section

Syntax `--no_rel_section`

For use with `ielfdumprh850`

Description By default, whenever the content of a section of a relocatable file is generated as output, the associated section, if any, is also included in the output. Use this option to suppress output of the relocation section.

This option is not available in the IDE.

--no_strtab

Syntax `--no_strtab`

For use with `ielfdumprh850`

Description Use this option to suppress dumping of string table sections (sections of type `SHT_STRTAB`).

This option is not available in the IDE.

--no_utf8_in

Syntax `--no_utf8_in`

For use with `ielfdumprh850`

Description

The dumper can normally determine whether ELF files produced by IAR tools use the UTF-8 text encoding or not, and produce the correct output. For ELF files produced by non-IAR tools, the dumper will assume UTF-8 encoding unless this option is used, in which case the encoding is assumed to be according to the current system default locale.

Note: This only makes a difference if any characters beyond 7-bit ASCII are used in paths, symbols, etc.

See also

Text encodings, page 246

This option is not available in the IDE.

--offset

Syntax

`--offset [-]`*`offset`*

Parameters

`offset`	The offset will be added (or subtracted if - is specified) to all addresses in the generated output file.

For use with

`ielftool`

Description

Use this option to add or subtract an offset to the address of each output record in the generated output file. The option only works on Motorola S-records, Intel Hex, TI-Txt, and Simple-Code. The option has no effect when generating an ELF file or when binary files (`--bin` contain no address information) are generated. No content, including the entry point, will be changed by using this option, only the addresses in the output format.

Example

```
--offset 0x30000
```

This will add an offset of `0x30000` to all addresses. As a result, content that was linked at address `0x4000` will be placed at `0x34000`.

This option is not available in the IDE.

--output, -o

Syntax

```
-o {filename|directory}
--output {filename|directory}
```

Parameters

See *Rules for specifying a filename or directory as parameters*, page 252.

For use with

`iarchive` and `ielfdumprh850`.

Description

`iarchive`

By default, `iarchive` assumes that the first argument after the `iarchive` command is the name of the destination library. Use this option to explicitly specify a different filename for the library.

`ielfdumprh850`

By default, output from the dumper is directed to the console. Use this option to direct the output to a file instead. The default name of the output file is the name of the input file with an added `id` filename extension

You can also specify the output file by specifying a file or directory following the name of the input file.

This option is not available in the IDE.

--parity

Syntax

`--parity{`*`symbol`*`[+`*`offset`*`]|`*`address`*`}:`*`size`*`,`*`algo`*`:`*`flashbase`*`[:`*`flags`*`];`*`ran`*
`ge``[;`*`range`*`...]`

Parameters

symbol	The name of the symbol where the parity bytes should be stored. Note that it must exist in the symbol table in the input ELF file.
offset	An offset to the symbol. By default, `0`.
address	The absolute address where the parity bytes should be stored.
size	The maximum number of bytes that the parity generation can use. An error will be issued if this value is exceeded. Note that the size must fit in the specified symbol in the ELF file.
algo	Choose between: `odd`, uses odd parity. `even`, uses even parity.

flashbase	The start address of the flash memory. Parity bits will not be generated for the addresses between *flashbase* and the start address of the range. If *flashbase* and the start address of the range coincide, parity bits will be generated for all addresses
flags	Choose between: `r`, reverses the byte order within each word. `L`, processes 4 bytes at a time. `W`, processes 2 bytes at a time. `B`, processes 1 byte at a time.
range	The address range over which the parity bytes should be generated. Hexadecimal and decimal notation are allowed, for example, `0x8002-0x8FFF`.

For use with

`ielftool`

Description

Use this option to generate parity bytes over specified ranges. The range is traversed left to the right and the parity bits are generated using the odd or even algorithm. The parity bits are finally stored in the specified symbol where they can be accessed by your application.

This option is not available in the IDE.

--ram_reserve_ranges

Syntax

`--ram_reserve_ranges[=`*symbol_prefix*`]`

Parameters

symbol_prefix	The prefix of symbols created by this option.

For use with

`isymexport`

Description

Use this option to generate symbols for the areas in RAM that the image uses. One symbol will be generated for each such area. The name of each symbol is based on the name of the area and is prefixed by the optional parameter *symbol_prefix*.

Generating symbols that cover an area in this way prevents the linker from placing other content at the affected addresses. This can be useful when linking against an existing image.

If `--ram_reserve_ranges` is used together with `--reserve_ranges`, the RAM areas will get their prefix from the `--ram_reserve_ranges` option and the non-RAM areas will get their prefix from the `--reserve_ranges` option.

See also

--*reserve_ranges*, page 520.

This option is not available in the IDE.

--range

Syntax

`--range start-end`

Parameters

start-end	Disassemble code where the start address is greater than or equal to *start*, and where the end address is less than *end*.

For use with

`ielfdumprh850`

Description

Use this option to specify a range for which code from an executable will be dumped.

This option is not available in the IDE.

--raw

Syntax

`--raw`

For use with

`ielfdumprh850`

Description

By default, many ELF sections will be dumped using a text format specific to a particular kind of section. Use this option to dump each selected ELF section using the generic text format.

The generic text format dumps each byte in the section in hexadecimal format, and where appropriate, as ASCII text.

This option is not available in the IDE.

--remove_file_path

Syntax `--remove_file_path`

For use with `iobjmanip`

Description Use this option to make `iobjmanip` remove information about the directory structure of the project source tree from the generated object file, which means that the file symbol in the ELF object file is modified.

This option must be used in combination with `--remove_section ".comment"`.

This option is not available in the IDE.

--remove_section

Syntax `--remove_section {`*`section`*`|`*`number`*`}`

Parameters

`section`	The section—or sections, if there are more than one section with the same name—to be removed.
`number`	The number of the section to be removed. Section numbers can be obtained from an object dump created using `ielfdumprh850`.

For use with `iobjmanip`

Description Use this option to make `iobjmanip` omit the specified section when generating the output file.

This option is not available in the IDE.

--rename_section

Syntax `--rename_section {`*`oldname`*`|`*`oldnumber`*`}=`*`newname`*

Parameters

`oldname`	The section—or sections, if there are more than one section with the same name—to be renamed.

oldnumber	The number of the section to be renamed. Section numbers can be obtained from an object dump created using `ielfdumprh850`.
newname	The new name of the section.

For use with `iobjmanip`

Description

Use this option to make `iobjmanip` rename the specified section when generating the output file.

This option is not available in the IDE.

--rename_symbol

Syntax

`--rename_symbol` *oldname* *=newname*

Parameters

oldname	The symbol to be renamed.
newname	The new name of the symbol.

For use with `iobjmanip`

Description

Use this option to make `iobjmanip` rename the specified symbol when generating the output file.

This option is not available in the IDE.

--replace, -r

Syntax

`--replace` *libraryfile objectfile1 ... objectfileN*
`-r` *libraryfile objectfile1 ... objectfileN*

Parameters

libraryfile	The library file that the command operates on. See *Rules for specifying a filename or directory as parameters*, page 252.
objectfile1 ... objectfileN	The object file(s) that the command operates on.

For use with `iarchive`

Description

Use this command to replace or add object files (modules) to an existing library. The object files specified on the command line either replace existing object files in the library—if they have the same name—or are appended to the library.

This option is not available in the IDE.

--reserve_ranges

Syntax

`--reserve_ranges[=`*`symbol_prefix`*`]`

Parameters

symbol_prefix	The prefix of symbols created by this option.

For use with `isymexport`

Description

Use this option to generate symbols for the areas in ROM and RAM that the image uses. One symbol will be generated for each such area. The name of each symbol is based on the name of the area and is prefixed by the optional parameter *`symbol_prefix`*.

Generating symbols that cover an area in this way prevents the linker from placing other content at the affected addresses. This can be useful when linking against an existing image.

If `--reserve_ranges` is used together with `--ram_reserve_ranges`, the RAM areas will get their prefix from the `--ram_reserve_ranges` option and the non-RAM areas will get their prefix from the `--reserve_ranges` option.

See also

--ram_reserve_ranges, page 516.

This option is not available in the IDE.

--section, -s

Syntax

```
--section section_number|section_name[,...]
--s section_number|section_name[,...]
```

Parameters

section_number	The number of the section to be dumped.

section_name	The name of the section to be dumped.

For use with

`ielfdumprh850`

Description

Use this option to dump the contents of a section with the specified number, or any section with the specified name. If a relocation section is associated with a selected section, its contents are output as well.

If you use this option, the general properties of the input file will not be included in the output.

You can specify multiple section numbers or names by separating them with commas, or by using this option more than once.

By default, no section contents are included in the output.

Example

```
-s 3,17                /* Sections #3 and #17
-s .debug_frame,42     /* Any sections named .debug_frame and
                          also section #42 */
```

This option is not available in the IDE.

--segment, -g

Syntax

`--segment` *segment_number*[,...]

`-g` *segment_number*[,...]

Parameters

segmnt_number	The number of a segment whose contents will be included in the output.

For use with

`ielfdumprh850`

Description

Use this option to select specific segments—parts of an executable image indicated by program headers—for inclusion in the output.

This option is not available in the IDE.

--self_reloc

Syntax `--self_reloc`

For use with `ielftool`

Description This option is intentionally not documented as it is not intended for general use.

This option is not available in the IDE.

--show_entry_as

Syntax `--show_entry_as` *`name`*

Parameters

`name`	The name to give to the program entry point in the output file.

For use with `isymexport`

Description Use this option to export the entry point of the application given as input under the name *`name`*.

This option is not available in the IDE.

--silent

Syntax `--silent`

For use with `ielftool`

Description Causes the tool to operate without sending any messages to the standard output stream.

By default, the tool sends various messages via the standard output stream. You can use this option to prevent this. The tool sends error and warning messages to the error output stream, so they are displayed regardless of this setting.

This option is not available in the IDE.

--simple

Syntax `--simple`

For use with `ielftool`

Description Sets the format of the output file to Simple-code, a binary format that includes address information.

To set related options, choose:

Project>Options>Output converter

--simple-ne

Syntax `--simple-ne`

For use with `ielftool`

Description Sets the format of the output file to Simple code, but no entry record is generated.

To set related options, choose:

Project>Options>Output converter

--source

Syntax `--source`

For use with `ielfdumprh850`

Description Use this option to make `ielftool` include source for each statement before the code for that statement, when dumping code from an executable file. To make this work, the executable image must be built with debug information, and the source code must still be accessible in its original location.

This option is not available in the IDE.

--srec

Syntax `--srec`

For use with `ielftool`

Description Sets the format of the output file to Motorola S-records, a hexadecimal text format defined by Motorola.

Note: You can use the `ielftool` options `--srec-len` and `--srec-s3only` to modify the exact format used.

To set related options, choose:

Project>Options>Output converter

--srec-len

Syntax `--srec-len=`*`length`*

Parameters

length	The number of data bytes in each S-record.

For use with `ielftool`

Description Sets the maximum number of data bytes in an S-record. This option can only be used together with the `--srec` option. By default, the number of data bytes in an S-record is 16.

This option is not available in the IDE.

--srec-s3only

Syntax `--srec-s3only`

For use with `ielftool`

Description Restricts the S-record output to contain only a subset of records, that is S0, S3 and S7 records. This option can be used in combination with the `--srec` option.

This option is not available in the IDE.

--strip

Syntax `--strip`

For use with `iobjmanip` and `ielftool`.

Description

Use this option to remove all sections containing debug information before the output file is written.

Note: `ielftool` needs an unstripped input ELF image. If you use the `--strip` option in the linker, remove it and use the `--strip` option in `ielftool` instead.

To set related options, choose:

Project>Options>Linker>Output>Include debug information in output

--symbols

Syntax `--symbols` *`libraryfile`*

Parameters

`libraryfile`	The library file that the command operates on. See *Rules for specifying a filename or directory as parameters*, page 252.

For use with `iarchive`

Description

Use this command to list all external symbols that are defined by any object file (module) in the specified library, together with the name of the object file (module) that defines it.

In silent mode (`--silent`), this command performs symbol table-related syntax checks on the library file and displays only errors and warnings.

This option is not available in the IDE.

--text_out

Syntax `--text_out{utf8|utf16le|utf16be|locale}`

Parameters

`utf8`	Uses the UTF-8 encoding
`utf16le`	Uses the UTF-16 little-endian encoding

`utf16be`	Uses the UTF-16 big-endian encoding
`locale`	Uses the system locale encoding

For use with

`iarchive`, `ielfdumprh850`, `iobjmanip`, and `isymexport`

Description

Use this option to specify the encoding to be used when generating a text output file.

The default for the list files is to use the same encoding as the main source file. The default for all other text files is UTF-8 with a Byte Order Mark (BOM).

If you want text output in UTF-8 encoding without BOM, you can use the option `--no_bom` as well.

See also

--no_bom, page 512 and *Text encodings*, page 246

This option is not available in the IDE.

--titxt

Syntax

`--titxt`

For use with

`ielftool`

Description

Sets the format of the output file to Texas Instruments TI–TXT, a hexadecimal text format defined by Texas Instruments.

To set related options, choose:

Project>Options>Output converter

--toc, -t

Syntax

```
--toc libraryfile
-t libraryfile
```

Parameters

`libraryfile`	The library file that the command operates on. See *Rules for specifying a filename or directory as parameters*, page 252.

For use with

`iarchive`

Description

Use this command to list the names of all object files (modules) in a specified library.

In silent mode (`--silent`), this command performs basic syntax checks on the library file, and displays only errors and warnings.

This option is not available in the IDE.

--use_full_std_template_names

Syntax `--use_full_std_template_names`

For use with `ielfdumprh850`

Description Normally, the names of some standard C++ templates are used in the output in an abbreviated form in the unmangled names of symbols, for example, `"std::string"` instead of `"std::basic_string<char, std::char_traits<char>, std_::allocator<char>>"`. Use this option to make `ielfdump` use the unabbreviated form.

This option is not available in the IDE.

--utf8_text_in

Syntax `--utf8_text_in`

For use with `iarchive`, `ielfdumprh850`, `iobjmanip`, and `isymexport`

Description Use this option to specify that the tool shall use the UTF-8 encoding when reading a text input file with no Byte Order Mark (BOM).

Note: This option does not apply to source files.

See also *Text encodings*, page 246

This option is not available in the IDE.

--verbose, -V

Syntax

```
--verbose
-V (iarchive only)
```

For use with `iarchive` and `ielftool`.

Description

Use this option to make the tool report which operations it performs, in addition to giving diagnostic messages.

This option is not available in the IDE because this setting is always enabled.

--version

Syntax

`--version`

For use with

`iarchive`, `ielfdumprh850`, `ielftool`, `iobjmanip`, `isymexport`

Description

Use this option to make the tool send version information to the console and then exit.

This option is not available in the IDE.

--vtoc

Syntax

`--vtoc` *`libraryfile`*

Parameters

`libraryfile`	The library file that the command operates on. See *Rules for specifying a filename or directory as parameters*, page 252.

For use with

`iarchive`

Description

Use this command to list the names, sizes, and modification times of all object files (modules) in a specified library.

In silent mode (`--silent`), this command performs basic syntax checks on the library file, and displays only errors and warnings.

This option is not available in the IDE.

Implementation-defined behavior for Standard C++

- Descriptions of implementation-defined behavior for C++
- Implementation quantities

If you are using C instead of C++, see *Implementation-defined behavior for Standard C*, page 549 or *Implementation-defined behavior for C89*, page 569, respectively.

Descriptions of implementation-defined behavior for C++

This section follows the same order as the C++ 14 standard. Each item includes references to the ISO chapter and section (in parenthesis) that explains the implementation-defined behavior.

Note: The IAR Systems implementation adheres to a freestanding implementation of Standard C++ 14. This means that parts of a standard library can be excluded from the implementation.

1 GENERAL

Diagnostics (1.3.6)

Diagnostics are produced in the form:

`filename,linenumber level[tag]: message`

where *`filename`* is the name of the source file in which the error was encountered, *`linenumber`* is the line number at which the compiler detected the error, *`level`* is the level of seriousness of the message (remark, warning, error, or fatal error), *`tag`* is a unique tag that identifies the message, and *`message`* is an explanatory message, possibly several lines.

Required libraries for freestanding implementation (1.4)

See *C++ header files*, page 415 and *Not supported C/C++ functionality*, page 419, respectively, for information about which Standard C++ system headers that the IAR C/C++ Compiler does not support.

Bits in a byte (1.7)

A byte contains 8 bits.

Interactive devices (1.9)

The streams `stdin`, `stdout`, and `stderr` are treated as interactive devices.

Number of threads in a program under a freestanding implementation (1.10)

By default, the IAR Systems runtime environment does not support more than one thread of execution. With an optional third-party RTOS, it might support several threads of execution.

2 LEXICAL CONVENTIONS

Mapping physical source file characters to the basic source character set (2.2)

The source character set is the same as the physical source file multibyte character set. By default, the standard ASCII character set is used. However, it can be UTF-8, UTF-16, or the system locale. See *Text encodings*, page 246.

Physical source file characters (2.2)

The source character set is the same as the physical source file multibyte character set. By default, the standard ASCII character set is used. However, it can be UTF-8, UTF-16, or the system locale. See *Text encodings*, page 246.

Converting characters from a source character set to the execution character set (2.2)

The source character set is the set of legal characters that can appear in source files. It is dependent on the chosen encoding for the source file. See *Text encodings*, page 246. By default, the source character set is Raw.

The execution character set is the set of legal characters that can appear in the execution environment. These are the execution character sets for character constants and string literals, and their encoding types:

Execution character set	Encoding type
`L`	UTF-32
`u`	UTF-16
`U`	UTF-32

Table 48: Execution character sets and their encodings

Execution character set	Encoding type
`u8`	UTF-8
`none`	The source character set

Table 48: Execution character sets and their encodings (Continued)

The DLIB runtime environment needs a multibyte character scanner to support a multibyte execution character set. See *Locale*, page 157.

Required availability of the source of translation units to locate template definitions (2.2)

When locating the template definition related to template instantiations, the source of the translation units that define the template is not required.

The execution character set and execution wide-character set (2.3)

The values of the members of the execution character set are the values of the ASCII character set, which can be augmented by the values of the extra characters in the source file character set. The source file character set is determined by the chosen encoding for the source file. See *Text encodings*, page 246.

The wide character set consists of all the code points defined by ISO/IEC 10646.

Mapping header names to headers or external source files (2.9)

The header name is interpreted and mapped into an external source file in the most intuitive way. In both forms of the `#include` preprocessing directive, the character sequences that specify header names are interpreted exactly in the same way as for other source constructs. They are then mapped to external header source file names.

The value of multi-character literals (2.14.3)

An integer character constant that contains more than one character will be treated as an integer constant. The value will be calculated by treating the leftmost character as the most significant character, and the rightmost character as the least significant character, in an integer constant. A diagnostic message is issued if the value cannot be represented in an integer constant.

The value of wide-character literals with single c-char that are not in the execution wide-character set (2.14.3)

All possible c-chars have a representation in the execution wide-character set.

The value of wide-character literal containing multiple characters (2.14.3)

A diagnostic message is issued, and all but the first c-char is ignored.

The semantics of non-standard escape sequences (2.14.3)

No non-standard escape sequences are supported.

The value of character literal outside range of corresponding type (2.14.3)

The value is truncated to fit the type.

The encoding of universal character name not in execution character set (2.14.3)

A diagnostic message is issued.

The choice of larger or smaller value of floating-point literal (2.14.4)

For a floating-point literal whose scaled value cannot be represented as a floating-point value, the nearest even floating point-value is chosen.

The distinctness of string literals (2.14.5)

All string literals are distinct except when the linker option `--merge_duplicate_sections` is used.

Concatenation of various types of string literals (2.14.5)

Differently prefixed string literal tokens cannot be concatenated, except for those specified by the ISO C++ standard.

3 BASIC CONCEPTS

Defining main in a freestanding environment (3.6.1)

The `main` function must be defined.

Startup and termination in a freestanding environment (3.6.1)

See *Application execution—an overview*, page 58 and *System startup and termination*, page 142, for descriptions of the startup and termination of applications.

Parameters to main (3.6.1)

The only two permitted definitions for `main` are:

```
int main()
int main(int, char **)
```

Linkage of main (3.6.1)

The `main` function has external linkage.

Dynamic initialization of static objects before main (3.6.2)

Static objects are initialized before the first statement of `main`, except when the linker option `--manual_dynamic_initialization` is used.

Dynamic initialization of threaded local objects before entry (3.6.2)

By default, the IAR systems runtime environment does not support more than one thread of execution. With an optional third-party RTOS, it might support several threads of execution.

Thread-local objects are treated as static objects except when the linker option `--threaded_lib` is used. Then they are initialized by the RTOS.

Use of an invalid pointer (3.7.4.2)

Any other use of an invalid pointer than indirection through it and passing it to a deallocation function works as for a valid pointer.

Relaxed or strict pointer safety for the implementation (3.7.4.3)

The IAR Systems implementation of Standard C++ has relaxed pointer safety.

The value of trivially copyable types (3.9)

All bits in basic types are part of the value representation. Padding between basic types is copied verbatim.

Representation and signage of char (3.9.1)

A plain `char` is treated as an `unsigned char`. See --*char_is_signed*, page 259 and --*char_is_unsigned*, page 259.

Extended signed integer types (3.9.1)

No extended signed integer types exist in the implementation.

Value representation of floating-point types (3.9.1)

See *Basic data types—floating-point types*, page 332.

Value representation of pointer types (3.9.2)

See *Pointer types*, page 334.

Alignment (3.11)

See *Alignment*, page 327.

Alignment additional values (3.11)

See *Alignment*, page 327.

alignof expression additional values (3.11)

See *Alignment*, page 327.

4 STANDARD CONVERSIONS

lvalue-to-rvalue conversion for objects that contain an invalid pointer (4.1)

The conversion is made as if the pointer was valid.

The value of the result of unsigned to signed conversion (4.7)

When an integer value is converted to a value of signed integer type, but cannot be represented by the destination type, the value is truncated to the number of bits of the destination type and then reinterpreted as a value of the destination type.

The result of inexact floating-point conversion (4.8)

When a floating-point value is converted to a value of a different floating-point type, and the value is within the range of the destination type but cannot be represented exactly, the value is rounded to the nearest floating-point value by default.

The value of the result of an inexact integer to floating-point conversion (4.9)

When an integer value is converted to a value of a floating-point type, and the value is within the range of the destination type but cannot be represented exactly, the value is rounded to the nearest floating-point value by default.

The rank of extended signed integer types (4.13)

The implementation has no extended signed integer types.

5 EXPRESSIONS

Passing argument of class type through ellipsis (5.2.2)

The result is a diagnostic and is then treated as a trivially copyable object.

The derived type for typeid (5.2.8)

The type of a `typeid` expression is an expression with dynamic type `std::type_info`.

Conversion from a pointer to an integer (5.2.10)

See *Casting*, page 334.

Conversion from an integer to a pointer (5.2.10)

See *Casting*, page 334.

Converting a function pointer to an object pointer and vice versa (5.2.10)

See *Casting*, page 334.

sizeof applied to fundamental types other than char, signed char, and unsigned char (5.3.3)

See *Basic data types—integer types*, page 328, *Basic data types—floating-point types*, page 332, and *Pointer types*, page 334.

Support for over-aligned types (5.3.4)

Over-aligned types are supported in `new` expressions.

The type of ptrdiff_t (5.7)

See *ptrdiff_t*, page 335.

The result of right shift of negative value (5.8)

In a bitwise right shift operation of the form `E1 >> E2`, if `E1` is of signed type and has a negative value, the value of the result is the integral part of the quotient `E1/(2**E2)`, except when `E1` is `-1`.

7 DECLARATIONS

The meaning of the attribute declaration (7)

There are no other attributes supported than what is specified in the C++ standard. See *Extended keywords*, page 341, for supported attributes and ways to use them with objects.

Access to an object that has volatile-qualified type (7.1.6.1)

See *Declaring objects volatile*, page 337.

The underlying type for enumeration (7.2)

See *The enum type*, page 329.

The meaning of the asm declaration (7.4)

An `asm` declaration enables the direct use of assembler instructions.

The semantics of linkage specifiers (7.5)

Only the string-literals `"C"` and `"C++"` can be used in a linkage specifier.

Linkage of objects to other languages than C (7.5)

The IAR Systems implementation of Standard C++ does not support linkage to other languages than C.

The behavior of attribute-scoped tokens (7.6.1)

The use of an attribute-scoped token is not supported.

The behavior of non-standard attributes (7.6.1)

There are no other attributes supported other than what is specified in the C++ standard. See *Extended keywords*, page 341, for a list supported attributes and ways to use them with objects.

8 DECLARATORS

The string resulting from __func__ (8.4.1)

The value of `__func__` is the C++ function name.

9 CLASSES

Allocation of bitfields within a class object (9.6)

See *Bitfields*, page 330.

14 TEMPLATES

The semantics of linkage specification on templates (14)

Only the string-literals `"C"` and `"C++"` can be used in a linkage specifier.

15 EXCEPTION HANDLING

Stack unwinding before calling std::terminate() (15.3, 15.5.1)

When no suitable catch handler is found, the stack is not unwound before calling `std::terminate()`.

Stack unwinding before calling std::terminate() when a noexcept specification is violated (15.5.1)

When a `noexcept` specification is violated, the stack is not unwound before calling `std::terminate()`.

Bad throw in std::unexpected (15.5.2)

If `std::unexpected` throws an exception that is not allowed by the exception specification for the function that caused the original exception specification violation, and that exception specification includes `std::bad_exception`, then the thrown exception is replaced by a `std::bad_exception` and the search for another handler continues.

16 PREPROCESSING DIRECTIVES

The numeric values of character literals in #if directives (16.1)

Numeric values of character literals in the `#if` and `#elif` preprocessing directives match the values that they have in other expressions.

Negative value of character literal in preprocessor (16.1)

A plain `char` is treated as an `unsigned char`. See *--char_is_signed*, page 259 and *--char_is_unsigned*, page 259. If a `char` is treated as a signed character, then character literals in `#if` and `#elif` preprocessing directives can be negative.

Search locations for < > header (16.2)

See *Include file search procedure*, page 243.

The search procedure for included source file (16.2)

See *Include file search procedure*, page 243.

Search locations for "" header (16.2)

See *Include file search procedure*, page 243.

The sequence of places searched for a header (16.2)

See *Include file search procedure*, page 243.

Nesting limit for #include directives (16.2)

The amount of available memory sets the limit.

#pragma (16.6)

See *Recognized pragma directives (6.10.6)*, page 557.

The definition and meaning of __STDC__ (16.8)

`__STDC__` is predefined to 1.

The text of __DATE__ when date of translation is not available (16.8)

The date of the translation is always available.

The text of __TIME__ when time of translation is not available (16.8)

The time of the translation is always available.

The definition and meaning of __STDC_VERSION__ (16.8)

`__STDC_VERSION__` is predefined to `201112L`.

17 LIBRARY INTRODUCTION

Headers for a freestanding implementation (17.6.1.3)

See *DLIB runtime environment—implementation details*, page 413.

Linkage of names from Standard C library (17.6.2.3)

Declarations from the C library have `"C"` linkage.

Functions in Standard C++ library that can be recursively reentered (17.6.5.8)

Functions can be recursively reentered, unless specified otherwise by the ISO C++ standard.

Exceptions thrown by standard library functions that do not have an exception specification (17.6.5.12)

These functions do not throw any additional exceptions.

error_category for errors originating outside of the operating system (17.6.5.14)

There is no additional error category.

18 LANGUAGE SUPPORT LIBRARY

Definition of NULL (18.2)

`NULL` is predefined as `0`.

The type of ptrdiff_t (18.2)

See *ptrdiff_t*, page 335.

The type of size_t (18.2)

See *size_t*, page 334.

Exit status (18.5)

Control is returned to the `__exit` library function. See *__exit*, page 149.

The return value of bad_alloc::what (18.6.2.1)

The return value is a pointer to `"bad allocation"`.

The return value of bad_array_new_length::what (18.6.2.2)

The return value is a pointer to `"bad allocation"`.

The return value of type_info::name() (18.7.1)

The return value is a pointer to a C string containing the name of the type.

The return value of bad_cast::what (18.7.2)

The return value is a pointer to `"bad cast"`.

The return value of bad_typeid::what (18.7.3)

The return value is a pointer to `"bad typeid"`.

The result of exception::what (18.8.1)

The return value is a pointer to `"unknown"`.

The return value of bad_exception::what (18.8.2)

The return value is a pointer to `"bad exception"`.

The use of non-POF functions as signal handlers (18.10)

Non-Plain Old Functions (POF) can be used as signal handlers if no uncaught exceptions are thrown in the handler, and if the execution of the signal handler does not trigger undefined behavior.

20 GENERAL UTILITIES LIBRARY

get_pointer_safety returning pointer_safety::relaxed or pointer_safety::preferred when the implementation has relaxed pointer safety (20.7.4)

The function `get_pointer_safety` always returns `std::pointer_safety::relaxed`.

Support for over-aligned types (20.7.9.1, 20.7.11)

Over-aligned types are supported.

The exception type when a shared_ptr constructor fails (20.8.2.2.1)

Only `std::bad_alloc` is thrown.

The assignability of placeholder objects (20.9.9.1.4)

Placeholder objects are `CopyAssignable`.

Support for extended alignment (20.10.7.6)

Extended alignment is supported.

Rounding or truncating values to the required precision when converting between time_t values and time_point objects (20.12.7.1)

Values are truncated to the required precision when converting between `time_t` values and `time_point` objects.

21 STRINGS LIBRARY

The type of streampos (21.2.3.1)

The type of `streampos` is `std::fpos<mbstate_t>`.

The type of streamoff (21.2.3.1)

The type of `streamoff` is `long`.

Supported multibyte character encoding rules (21.2.3.1)

See *Locale*, page 157.

The type of u16streampos (21.2.3.2)

The type of `u16streampos` is `streampos`.

The return value of char_traits<char16_t>::eof (21.2.3.2)

The return value of `char_traits<char16_t>::eof` is `EOF`.

The type of u32streampos (21.2.3.3)

The type of `u32streampos` is `streampos`.

The return value of char_traits<char32_t>::eof (21.2.3.3)

The return value of `char_traits<char32_t>::eof` is `EOF`.

The type of wstreampos (21.2.3.4)

The type of `wstreampos` is `streampos`.

The return value of char_traits<wchar_t>::eof (21.2.3.3)

The return value of `char_traits<wchar_t>::eof` is `EOF`.

22 LOCALIZATION LIBRARY

Locale object being global or per-thread (22.3.1)

There is one global locale object for the entire application.

Locale names (22.3.1.2)

See *Locale*, page 157.

The effects on the C locale of calling locale::global (22.3.1.5)

Calling this function with an unnamed locale has no effect.

The value of ctype<char>::table_size (22.4.1.3)

The value of `ctype<char>::table_size` is 256.

Additional formats for time_get::do_get_date (22.4.5.1.2)

No additional formats are accepted for `time_get::do_get_date`.

time_get::do_get_year and two-digit year numbers (22.4.5.1.2)

Two-digit year numbers are accepted by `time_get::do_get_year`. Years from 0 to 68 are parsed as meaning 2000 to 2068, and years from 69 to 99 are parsed as meaning 1969 to 1999.

Formatted character sequences generated by time_put::do_put in the C locale (22.4.5.3.1)

The behavior is the same as that of the library function `strftime`.

Mapping from name to catalog when calling messages::do_open (22.4.7.1.2)

No mapping occurs because this function does not open a catalog.

Mapping to message when calling messages::do_get (22.4.7.1.2)

No mapping occurs because this function does not open a catalog. `dflt` is returned.

Mapping to message when calling messages::do_close (22.4.7.1.2)

The function cannot be called because no catalog can be open.

23 CONTAINERS LIBRARY

The type of array::iterator (23.3.2.1)

The type of `array::iterator` is `T *`.

The type of array::const_iterator (23.3.2.1)

The type of `array::const_iterator` is `T const *`.

The default number of buckets in unordered_map (23.5.4.2)

The IAR C/C++ Compiler for RH850 makes a default construction of the `unordered_map` before inserting the elements.

The default number of buckets in unordered_multimap (23.5.5.2)

The IAR C/C++ Compiler for RH850 makes a default construction of the `unordered_multimap` before inserting the elements.

The default number of buckets in unordered_set (23.5.6.2)

The IAR C/C++ Compiler for RH850 makes a default construction of the `unordered_set` before inserting the elements.

The default number of buckets in unordered_multiset (23.5.7.2)

The IAR C/C++ Compiler for RH850 makes a default construction of the `unordered_multiset` before inserting the elements.

25 ALGORITHMS LIBRARY

The underlying source of random numbers for random_shuffle (25.3.12)

The underlying source is `rand()`.

27 INPUT/OUTPUT LIBRARY

The behavior of iostream classes when traits::pos_type is not streampos or when traits::off_type is not streamoff (27.2.2)

No specific behavior has been implemented for this case.

The effects of calling ios_base::sync_with_stdio after any input or output operation on standard streams (27.5.3.4)

Previous input/output is not handled in any special way.

Argument values to construct basic_ios::failure (27.5.5.4)

When `basic_ios::clear` throws an exception, it throws an exception of type `basic_ios::failure` constructed with the `badbit`/`failbit`/`eofbit` set.

The basic_stringbuf move constructor and the copying of sequence pointers (27.8.2.1)

The constructor copies the sequence pointers.

The effects of calling basic_streambuf::setbuf with non-zero arguments (27.8.2.4)

This function has no effect.

The basic_filebuf move constructor and the copying of sequence pointers (27.9.1.2)

The constructor copies the sequence pointers.

The effects of calling basic_filebuf::setbuf with non-zero arguments (27.9.1.5)

This will offer the buffer to the C stream by calling `setvbuf()` with the associated file. If anything goes wrong, the stream is reinitialized.

The effects of calling basic_filebuf::sync when a get area exists (27.9.1.5)

A `get` area cannot exist.

28 REGULAR EXPRESSIONS LIBRARY

The type of regex_constants::error_type (28.5.3)

The type is an `enum`. See *The enum type*, page 329.

29 ATOMIC OPERATIONS LIBRARY

The values of various ATOMIC_..._LOCK_FREE macros (29.4)

In cases where atomic operations are supported, these macros will have the value 2. See *Atomic operations*, page 419.

30 THREAD SUPPORT LIBRARY

The presence and meaning of native_handle_type and native_handle (30.2.3)

The `thread` system header is not supported.

ANNEX D (NORMATIVE): COMPATIBILITY FEATURES

The type of ios_base::streamoff (D.6)

The type of `ios_base::streamoff` is `std::streamoff`.

The type of ios_base::streampos (D.6)

The type of `ios_base::streampos` is `std::streampos`.

Implementation quantities

The IAR Systems implementation of C++ is, like all implementations, limited in the size of the applications it can successfully process.

These limitations apply:

C++ feature	Limitation
Nesting levels of compound statements, iteration control structures, and selection control structures.	Limited only by memory.
Nesting levels of conditional inclusion.	Limited only by memory.
Pointer, array, and function declarators (in any combination) modifying a class, arithmetic, or incomplete type in a declaration.	Limited only by memory.
Nesting levels of parenthesized expressions within a full-expression.	Limited only by memory.
Number of characters in an internal identifier or macro name.	Limited only by memory.

Table 49: C++ implementation quantities

C++ feature	Limitation
Number of characters in an external identifier.	Limited only by memory.
External identifiers in one translation unit.	Limited only by memory.
Identifiers with block scope declared in a block.	Limited only by memory.
Macro identifiers simultaneously defined in one translation unit.	Limited only by memory.
Parameters in one function definition.	Limited only by memory.
Arguments in one function call.	Limited only by memory.
Parameters in one macro definition.	Limited only by memory.
Arguments in one macro invocation.	Limited only by memory.
Characters in one logical source line.	Limited only by memory.
Characters in a string literal (after concatenation).	Limited only by memory.
Size of an object.	Limited only by memory.
Nesting levels for `#include` files.	Limited only by memory.
Case labels for a switch statement (excluding those for any nested switch statements).	Limited only by memory.
Data members in a single class.	Limited only by memory.
Enumeration constants in a single enumeration.	Limited only by memory.
Levels of nested class definitions in a single member-specification.	Limited only by memory.
Functions registered by `atexit`.	Limited by heap memory in the built application.
Functions registered by `at_quick_exit`.	Limited by heap memory in the built application.
Direct and indirect base classes.	Limited only by memory.
Direct base classes for a single class.	Limited only by memory.
Members declared in a single class.	Limited only by memory.
Final overriding virtual functions in a class, accessible or not.	Limited only by memory.
Direct and indirect virtual bases of a class.	Limited only by memory.
Static members of a class.	Limited only by memory.
Friend declarations in a class.	Limited only by memory.
Access control declarations in a class.	Limited only by memory.
Member initializers in a constructor definition.	Limited only by memory.

Table 49: C++ implementation quantities (Continued)

C++ feature	Limitation
Scope qualifiers of one identifier.	Limited only by memory.
Nested external specifications.	Limited only by memory.
Recursive `constexpr` function invocations.	1000. This limit can be changed by using the compiler option `--max_cost_constexpr_call`.
Full-expressions evaluated within a core constant expression.	Limited only by memory.
Template arguments in a template declaration.	Limited only by memory.
Recursively nested template instantiations, including substitution during template argument deduction (14.8.2).	64 for a specific template. This limit can be changed by using the compiler option `--pending_instantiations`.
Handlers per try block.	Limited only by memory.
Throw specifications on a single function declaration.	Limited only by memory.
Number of placeholders (20.9.9.1.4).	20 placeholders from `_1` to `_20`.

Table 49: C++ implementation quantities (Continued)

Implementation-defined behavior for Standard C

- Descriptions of implementation-defined behavior

If you are using C89 instead of Standard C, see *Implementation-defined behavior for C89*, page 569.

Descriptions of implementation-defined behavior

This section follows the same order as the C standard. Each item includes references to the ISO chapter and section (in parenthesis) that explains the implementation-defined behavior.

Note: The IAR Systems implementation adheres to a freestanding implementation of Standard C. This means that parts of a standard library can be excluded in the implementation.

J.3.1 TRANSLATION

Diagnostics (3.10, 5.1.1.3)

Diagnostics are produced in the form:

`filename,linenumber level[tag]: message`

where *`filename`* is the name of the source file in which the error was encountered, *`linenumber`* is the line number at which the compiler detected the error, *`level`* is the level of seriousness of the message (remark, warning, error, or fatal error), *`tag`* is a unique tag that identifies the message, and *`message`* is an explanatory message, possibly several lines.

White-space characters (5.1.1.2)

At translation phase three, each non-empty sequence of white-space characters is retained.

J.3.2 ENVIRONMENT

The character set (5.1.1.2)

The source character set is the same as the physical source file multibyte character set. By default, the standard ASCII character set is used. However, it can be UTF-8, UTF-16, or the system locale. See *Text encodings*, page 246.

Main (5.1.2.1)

The function called at program startup is called `main`. No prototype is declared for `main`, and the only definition supported for `main` is:

```
int main(void)
```

To change this behavior, see *System initialization*, page 146.

The effect of program termination (5.1.2.1)

Terminating the application returns the execution to the startup code (just after the call to `main`).

Alternative ways to define main (5.1.2.2.1)

There is no alternative ways to define the `main` function.

The argv argument to main (5.1.2.2.1)

The `argv` argument is not supported.

Streams as interactive devices (5.1.2.3)

The streams `stdin`, `stdout`, and `stderr` are treated as interactive devices.

Multi-threaded environment (5.1.2.4)

By default, the IAR Systems runtime environment does not support more than one thread of execution. With an optional third-party RTOS, it might support several threads of execution.

Signals, their semantics, and the default handling (7.14)

In the DLIB runtime environment, the set of supported signals is the same as in Standard C. A raised signal will do nothing, unless the `signal` function is customized to fit the application.

Signal values for computational exceptions (7.14.1.1)

In the DLIB runtime environment, there are no implementation-defined values that correspond to a computational exception.

Signals at system startup (7.14.1.1)

In the DLIB runtime environment, there are no implementation-defined signals that are executed at system startup.

Environment names (7.22.4.6)

In the DLIB runtime environment, there are no implementation-defined environment names that are used by the `getenv` function.

The system function (7.22.4.8)

The `system` function is not supported.

J.3.3 IDENTIFIERS

Multibyte characters in identifiers (6.4.2)

Additional multibyte characters may appear in identifiers depending on the chosen encoding for the source file. The supported multibyte characters must be translatable to one Universal Character Name (UCN).

Significant characters in identifiers (5.2.4.1, 6.4.2)

The number of significant initial characters in an identifier with or without external linkage is guaranteed to be no less than 200.

J.3.4 CHARACTERS

Number of bits in a byte (3.6)

A byte contains 8 bits.

Execution character set member values (5.2.1)

The values of the members of the execution character set are the values of the ASCII character set, which can be augmented by the values of the extra characters in the source file character set. The source file character set is determined by the chosen encoding for the source file. See *Text encodings*, page 246.

Alphabetic escape sequences (5.2.2)

The standard alphabetic escape sequences have the values `\a–7`, `\b–8`, `\f–12`, `\n–10`, `\r–13`, `\t–9`, and `\v–11`.

Characters outside of the basic executive character set (6.2.5)

A character outside of the basic executive character set that is stored in a `char` is not transformed.

Plain char (6.2.5, 6.3.1.1)

A plain `char` is treated as an `unsigned char`. See *--char_is_signed*, page 259 and *--char_is_unsigned*, page 259.

Source and execution character sets (6.4.4.4, 5.1.1.2)

The source character set is the set of legal characters that can appear in source files. It is dependent on the chosen encoding for the source file. See *Text encodings*, page 246. By default, the source character set is Raw.

The execution character set is the set of legal characters that can appear in the execution environment. These are the execution character set for character constants and string literals and their encoding types:

Execution character set	Encoding type
`L`	UTF-32
`u`	UTF-16
`U`	UTF-32
`u8`	UTF-8
`none`	The source character set

Table 50: Execution character sets and their encodings

The DLIB runtime environment needs a multibyte character scanner to support a multibyte execution character set. See *Locale*, page 157.

Integer character constants with more than one character (6.4.4.4)

An integer character constant that contains more than one character will be treated as an integer constant. The value will be calculated by treating the leftmost character as the most significant character, and the rightmost character as the least significant character, in an integer constant. A diagnostic message will be issued if the value cannot be represented in an integer constant.

Wide character constants with more than one character (6.4.4.4)

A wide character constant that contains more than one multibyte character generates a diagnostic message.

Locale used for wide character constants (6.4.4.4)

See *Source and execution character sets (6.4.4.4, 5.1.1.2)*, page 552.

Concatenating wide string literals with different encoding types (6.4.5)

Wide string literals with different encoding types cannot be concatenated.

Locale used for wide string literals (6.4.5)

See *Source and execution character sets (6.4.4.4, 5.1.1.2)*, page 552.

Source characters as executive characters (6.4.5)

All source characters can be represented as executive characters.

Encoding of wchar_t, char16_t, and char32_t (6.10.8.2)

`wchar_t` has the encoding UTF-32, `char16_t` has the encoding UTF-16, and `char32_t` has the encoding UTF-32.

J.3.5 INTEGERS

Extended integer types (6.2.5)

There are no extended integer types.

Range of integer values (6.2.6.2)

The representation of integer values are in the two's complement form. The most significant bit holds the sign—1 for negative, 0 for positive and zero.

For information about the ranges for the different integer types, see *Basic data types—integer types*, page 328.

The rank of extended integer types (6.3.1.1)

There are no extended integer types.

Signals when converting to a signed integer type (6.3.1.3)

No signal is raised when an integer is converted to a signed integer type.

Signed bitwise operations (6.5)

Bitwise operations on signed integers work the same way as bitwise operations on unsigned integers—in other words, the sign-bit will be treated as any other bit, except for the operator >> which will behave as an arithmetic right shift.

J.3.6 FLOATING POINT

Accuracy of floating-point operations (5.2.4.2.2)

The accuracy of floating-point operations is unknown.

Accuracy of floating-point conversions (5.2.4.2.2)

The accuracy of floating-point conversions is unknown.

Rounding behaviors (5.2.4.2.2)

There are no non-standard values of `FLT_ROUNDS`.

Evaluation methods (5.2.4.2.2)

There are no non-standard values of `FLT_EVAL_METHOD`.

Converting integer values to floating-point values (6.3.1.4)

When an integer value is converted to a floating-point value that cannot exactly represent the source value, the round-to-nearest rounding mode is used (`FLT_ROUNDS` is defined to 1).

Converting floating-point values to floating-point values (6.3.1.5)

When a floating-point value is converted to a floating-point value that cannot exactly represent the source value, the round-to-nearest rounding mode is used (`FLT_ROUNDS` is defined to 1).

Denoting the value of floating-point constants (6.4.4.2)

The round-to-nearest rounding mode is used (`FLT_ROUNDS` is defined to 1).

Contraction of floating-point values (6.5)

Floating-point values are contracted. However, there is no loss in precision and because signaling is not supported, this does not matter.

Default state of FENV_ACCESS (7.6.1)

The default state of the pragma directive `FENV_ACCESS` is `OFF`.

Additional floating-point mechanisms (7.6, 7.12)

There are no additional floating-point exceptions, rounding-modes, environments, and classifications.

Default state of FP_CONTRACT (7.12.2)

The default state of the pragma directive `FP_CONTRACT` is `OFF`.

J.3.7 ARRAYS AND POINTERS

Conversion from/to pointers (6.3.2.3)

For information about casting of data pointers and function pointers, see *Casting*, page 334.

ptrdiff_t (6.5.6)

For information about `ptrdiff_t`, see *ptrdiff_t*, page 335.

J.3.8 HINTS

Honoring the register keyword (6.7.1)

User requests for register variables are not honored.

Inlining functions (6.7.4)

User requests for inlining functions increases the chance, but does not make it certain, that the function will actually be inlined into another function. See *Inlining functions*, page 85.

J.3.9 STRUCTURES, UNIONS, ENUMERATIONS, AND BITFIELDS

Sign of 'plain' bitfields (6.7.2, 6.7.2.1)

For information about how a 'plain' `int` bitfield is treated, see *Bitfields*, page 330.

Possible types for bitfields (6.7.2.1)

All integer types can be used as bitfields in the compiler's extended mode, see *-e*, page 267.

Atomic types for bitfields (6.7.2.1)

Atomic types cannot be used as bitfields.

Bitfields straddling a storage-unit boundary (6.7.2.1)

A bitfield is always placed in one—and one only—storage unit, which means that the bitfield cannot straddle a storage-unit boundary.

Allocation order of bitfields within a unit (6.7.2.1)

For information about how bitfields are allocated within a storage unit, see *Bitfields*, page 330.

Alignment of non-bitfield structure members (6.7.2.1)

The alignment of non-bitfield members of structures is the same as for the member types, see *Alignment*, page 327.

Integer type used for representing enumeration types (6.7.2.2)

The chosen integer type for a specific enumeration type depends on the enumeration constants defined for the enumeration type. The chosen integer type is the smallest possible.

J.3.10 QUALIFIERS

Access to volatile objects (6.7.3)

Any reference to an object with `volatile` qualified type is an access, see *Declaring objects volatile*, page 337.

J.3.11 PREPROCESSING DIRECTIVES

Locations in #pragma for header names (6.4, 6.4.7)

These pragma directives take header names as parameters at the specified positions:

```
#pragma include_alias ("header", "header")
#pragma include_alias (<header>, <header>)
```

Mapping of header names (6.4.7)

Sequences in header names are mapped to source file names verbatim. A backslash '\' is not treated as an escape sequence. See *Overview of the preprocessor*, page 403.

Character constants in constant expressions (6.10.1)

A character constant in a constant expression that controls conditional inclusion matches the value of the same character constant in the execution character set.

The value of a single-character constant (6.10.1)

A single-character constant may only have a negative value if a plain character (`char`) is treated as a signed character, see *--char_is_signed*, page 259.

Including bracketed filenames (6.10.2)

For information about the search algorithm used for file specifications in angle brackets `<>`, see *Include file search procedure*, page 243.

Including quoted filenames (6.10.2)

For information about the search algorithm used for file specifications enclosed in quotes, see *Include file search procedure*, page 243.

Preprocessing tokens in #include directives (6.10.2)

Preprocessing tokens in an `#include` directive are combined in the same way as outside an `#include` directive.

Nesting limits for #include directives (6.10.2)

There is no explicit nesting limit for `#include` processing.

inserts \ in front of \u (6.10.3.2)

`#` (stringify argument) inserts a `\` character in front of a Universal Character Name (UCN) in character constants and string literals.

Recognized pragma directives (6.10.6)

In addition to the pragma directives described in the chapter *Pragma directives*, the following directives are recognized and will have an indeterminate effect. If a pragma directive is listed both in the chapter *Pragma directives* and here, the information provided in the chapter *Pragma directives* overrides the information here.

`alias_def`

`alignment`

`alternate_target_def`

`baseaddr`

`basic_template_matching`

`building_runtime`

`can_instantiate`

```
codeseg
cplusplus_neutral
cspy_support
cstat_dump
define_type_info
do_not_instantiate
early_dynamic_initialization
exception_neutral
function
function_category
function_effects
hdrstop
important_typedef
ident
implements_aspect
init_routines_only_for_needed_variables
initialization_routine
inline_template
instantiate
keep_definition
library_default_requirements
library_provides
library_requirement_override
memory
module_name
no_pch
no_vtable_use
once
pop_macro
```

`preferred_typedef`

`push_macro`

`separate_init_routine`

`set_generate_entries_without_bounds`

`system_include`

`uses_aspect`

`warnings`

Default __DATE__ and __TIME__ (6.10.8)

The definitions for `__TIME__` and `__DATE__` are always available.

J.3.12 LIBRARY FUNCTIONS

Additional library facilities (5.1.2.1)

Most of the standard library facilities are supported. Some of them—the ones that need an operating system—require a low-level implementation in the application. For more information, see *The DLIB runtime environment*, page 123.

Diagnostic printed by the assert function (7.2.1.1)

The `assert()` function prints:

filename:*linenr expression* -- assertion failed

when the parameter evaluates to zero.

Representation of the floating-point status flags (7.6.2.2)

For information about the floating-point status flags, see *fenv.h*, page 420.

Feraiseexcept raising floating-point exception (7.6.2.3)

For information about the `feraiseexcept` function raising floating-point exceptions, see *Floating-point environment*, page 332.

Strings passed to the setlocale function (7.11.1.1)

For information about strings passed to the `setlocale` function, see *Locale*, page 157.

Types defined for float_t and double_t (7.12)

The `FLT_EVAL_METHOD` macro can only have the value `0`.

Domain errors (7.12.1)

No function generates other domain errors than what the standard requires.

Return values on domain errors (7.12.1)

Mathematic functions return a floating-point `NaN` (not a number) for domain errors.

Underflow errors (7.12.1)

Mathematic functions set `errno` to the macro `ERANGE` (a macro in `errno.h`) and return zero for underflow errors.

fmod return value (7.12.10.1)

The `fmod` function sets `errno` to a domain error and returns a floating-point `NaN` when the second argument is zero.

remainder return value (7.12.10.2)

The `remainder` function sets `errno` to a domain error and returns a floating-point NaN when the second argument is zero.

The magnitude of remquo (7.12.10.3)

The magnitude is congruent modulo `INT_MAX`.

remquo return value (7.12.10.3)

The `remquo` function sets `errno` to a domain error and returns a floating-point NaN when the second argument is zero.

signal() (7.14.1.1)

The signal part of the library is not supported.

Note: The default implementation of `signal` does not perform anything. Use the template source code to implement application-specific signal handling. See *signal*, page 154 and *raise*, page 152, respectively.

NULL macro (7.19)

The `NULL` macro is defined to `0`.

Terminating newline character (7.21.2)

Stream functions recognize either `newline` or `end of file (EOF)` as the terminating character for a line.

Space characters before a newline character (7.21.2)

Space characters written to a stream immediately before a newline character are preserved.

Null characters appended to data written to binary streams (7.21.2)

No null characters are appended to data written to binary streams.

File position in append mode (7.21.3)

The file position is initially placed at the beginning of the file when it is opened in append-mode.

Truncation of files (7.21.3)

Whether a write operation on a text stream causes the associated file to be truncated beyond that point, depends on the application-specific implementation of the low-level file routines. See *Briefly about input and output (I/O)*, page 124.

File buffering (7.21.3)

An open file can be either block-buffered, line-buffered, or unbuffered.

A zero-length file (7.21.3)

Whether a zero-length file exists depends on the application-specific implementation of the low-level file routines.

Legal file names (7.21.3)

The legality of a filename depends on the application-specific implementation of the low-level file routines.

Number of times a file can be opened (7.21.3)

Whether a file can be opened more than once depends on the application-specific implementation of the low-level file routines.

Multibyte characters in a file (7.21.3)

The encoding of multibyte characters in a file depends on the application-specific implementation of the low-level file routines.

remove() (7.21.4.1)

The effect of a remove operation on an open file depends on the application-specific implementation of the low-level file routines. See *Briefly about input and output (I/O)*, page 124.

rename() (7.21.4.2)

The effect of renaming a file to an already existing filename depends on the application-specific implementation of the low-level file routines. See *Briefly about input and output (I/O)*, page 124.

Removal of open temporary files (7.21.4.3)

Whether an open temporary file is removed depends on the application-specific implementation of the low-level file routines.

Mode changing (7.21.5.4)

`freopen` closes the named stream, then reopens it in the new mode. The streams `stdin`, `stdout`, and `stderr` can be reopened in any new mode.

Style for printing infinity or NaN (7.21.6.1, 7.29.2.1)

The style used for printing infinity or `NaN` for a floating-point constant is `inf` and `nan` (`INF` and `NAN` for the `F` conversion specifier), respectively. The n-char-sequence is not used for `nan`.

%p in printf() (7.21.6.1, 7.29.2.1)

The argument to a `%p` conversion specifier, print pointer, to `printf()` is treated as having the type `void *`. The value will be printed as a hexadecimal number, similar to using the `%x` conversion specifier.

Reading ranges in scanf (7.21.6.2, 7.29.2.1)

A `-` (dash) character is always treated as a range symbol.

%p in scanf (7.21.6.2, 7.29.2.2)

The `%p` conversion specifier, scan pointer, to `scanf()` reads a hexadecimal number and converts it into a value with the type `void *`.

File position errors (7.21.9.1, 7.21.9.3, 7.21.9.4)

On file position errors, the functions `fgetpos`, `ftell`, and `fsetpos` store `EFPOS` in `errno`.

An n-char-sequence after nan (7.22.1.3, 7.29.4.1.1)

An n-char-sequence after a NaN is read and ignored.

errno value at underflow (7.22.1.3, 7.29.4.1.1)

`errno` is set to `ERANGE` if an underflow is encountered.

Zero-sized heap objects (7.22.3)

A request for a zero-sized heap object will return a valid pointer and not a null pointer.

Behavior of abort and exit (7.22.4.1, 7.22.4.5)

A call to `abort()` or `_Exit()` will not flush stream buffers, not close open streams, and not remove temporary files.

Termination status (7.22.4.1, 7.22.4.4, 7.22.4.5, 7.22.4.7)

The termination status will be propagated to `__exit()` as a parameter. `exit()`, `_Exit()`, and `quick_exit` use the input parameter, whereas abort uses `EXIT_FAILURE`.

The system function return value (7.22.4.8)

The `system` function returns -1 when its argument is not a null pointer.

Range and precision of clock_t and time_t (7.27)

The range and precision of `clock_t` is up to your implementation. The range and precision of `time_t` is 19000101 up to 20351231 in tics of a second if the 32-bit `time_t` is used. It is -9999 up to 9999 years in tics of a second if the 64-bit `time_t` is used. See *time.h*, page 421

The time zone (7.27.1)

The local time zone and daylight savings time must be defined by the application. For more information, see *time.h*, page 421.

The era for clock() (7.27.2.1)

The era for the `clock` function is up to your implementation.

TIME_UTC epoch (7.27.2.5)

The epoch for `TIME_UTC` is up to your implementation.

%Z replacement string (7.27.3.5, 7.29.5.1)

By default, ":" or "" (an empty string) is used as a replacement for `%Z`. Your application should implement the time zone handling. See *__time32, __time64*, page 155.

Math functions rounding mode (F.10)

The functions in `math.h` honor the rounding direction mode in `FLT-ROUNDS`.

J.3.13 ARCHITECTURE

Values and expressions assigned to some macros (5.2.4.2, 7.20.2, 7.20.3)

There are always 8 bits in a byte.

`MB_LEN_MAX` is at the most 6 bytes depending on the library configuration that is used.

For information about sizes, ranges, etc for all basic types, see *Data representation*, page 327.

The limit macros for the exact-width, minimum-width, and fastest minimum-width integer types defined in `stdint.h` have the same ranges as `char`, `short`, `int`, `long`, and `long long`.

The floating-point constant `FLT_ROUNDS` has the value 1 (to nearest) and the floating-point constant `FLT_EVAL_METHOD` has the value 0 (treat as is).

Accessing another thread's autos or thread locals (6.2.4)

The IAR Systems runtime environment does not allow multiple threads. With a third-party RTOS, the access will take place and work as intended as long as the accessed item has not gone out of its scope.

The number, order, and encoding of bytes (6.2.6.1)

See *Data representation*, page 327.

Extended alignments (6.2.8)

For information about extended alignments, see *data_alignment*, page 364.

Valid alignments (6.2.8)

For information about valid alignments on fundamental types, see the chapter *Data representation*.

The value of the result of the sizeof operator (6.5.3.4)

See *Data representation*, page 327.

J.4 LOCALE

Members of the source and execution character set (5.2.1)

By default, the compiler accepts all one-byte characters in the host's default character set. The chapter *Encodings* describes how to change the default encoding for the source character set, and by that the encoding for plain character constants and plain string literals in the execution character set.

The meaning of the additional characters (5.2.1.2)

Any multibyte characters in the extended source character set is translated into the following encoding for the execution character set:

Execution character set	Encoding
`L` typed	UTF-32
`u` typed	UTF-16
`U` typed	UTF-32
`u8` typed	UTF-8
none typed	The same as the source character set

Table 51: Translation of multibyte characters in the extended source character set

It is up to your application with the support of the library configuration to handle the characters correctly.

Shift states for encoding multibyte characters (5.2.1.2)

No shift states are supported.

Direction of successive printing characters (5.2.2)

The application defines the characteristics of a display device.

The decimal point character (7.1.1)

For a library with the configuration Normal or Tiny, the default decimal-point character is a '.'. For a library with the configuration Full, the chosen locale defines what character is used for the decimal point.

Printing characters (7.4, 7.30.2)

The set of printing characters is determined by the chosen locale.

Control characters (7.4, 7.30.2)

The set of control characters is determined by the chosen locale.

Characters tested for (7.4.1.2, 7.4.1.3, 7.4.1.7, 7.4.1.9, 7.4.1.10, 7.4.1.11, 7.30.2.1.2, 7.30.5.1.3, 7.30.2.1.7, 7.30.2.1.9, 7.30.2.1.10, 7.30.2.1.11)

The set of characters tested for the character-based functions are determined by the chosen locale. The set of characters tested for the `wchar_t`-based functions are the UTF-32 code points `0x0` to `0x7F`.

The native environment (7.11.1.1)

The native environment is the same as the "C" locale.

Subject sequences for numeric conversion functions (7.22.1, 7.29.4.1)

There are no additional subject sequences that can be accepted by the numeric conversion functions.

The collation of the execution character set (7.24.4.3, 7.29.4.4.2)

Collation is not supported.

Message returned by strerror (7.24.6.2)

The messages returned by the `strerror` function depending on the argument is:

Argument	Message
`EZERO`	`no error`
`EDOM`	`domain error`
`ERANGE`	`range error`
`EFPOS`	`file positioning error`
`EILSEQ`	`multi-byte encoding error`
`<0 || >99`	`unknown error`
all others	`error` *nnn*

Table 52: Message returned by strerror()—DLIB runtime environment

Formats for time and date (7.27.3.5, 7.29.5.1)

Time zone information is as you have implemented it in the low-level function `__getzone`.

Character mappings (7.30.1)

The character mappings supported are `tolower` and `toupper`.

Character classifications (7.30.1)

The character classifications that are supported are `alnum`, `cntrl`, `digit`, `graph`, `lower`, `print`, `punct`, `space`, `upper`, and `xdigit`.

Implementation-defined behavior for C89

- Descriptions of implementation-defined behavior

If you are using Standard C instead of C89, see *Implementation-defined behavior for Standard C*, page 549.

Descriptions of implementation-defined behavior

The descriptions follow the same order as the ISO appendix. Each item covered includes references to the ISO chapter and section (in parenthesis) that explains the implementation-defined behavior.

TRANSLATION

Diagnostics (5.1.1.3)

Diagnostics are produced in the form:

`filename,linenumber level[tag]: message`

where *`filename`* is the name of the source file in which the error was encountered, *`linenumber`* is the line number at which the compiler detected the error, *`level`* is the level of seriousness of the message (remark, warning, error, or fatal error), *`tag`* is a unique tag that identifies the message, and *`message`* is an explanatory message, possibly several lines.

ENVIRONMENT

Arguments to main (5.1.2.2.2.1)

The function called at program startup is called `main`. No prototype was declared for `main`, and the only definition supported for `main` is:

```
int main(void)
```

To change this behavior for the DLIB runtime environment, see *System initialization*, page 146.

Interactive devices (5.1.2.3)

The streams `stdin` and `stdout` are treated as interactive devices.

IDENTIFIERS

Significant characters without external linkage (6.1.2)

The number of significant initial characters in an identifier without external linkage is 200.

Significant characters with external linkage (6.1.2)

The number of significant initial characters in an identifier with external linkage is 200.

Case distinctions are significant (6.1.2)

Identifiers with external linkage are treated as case-sensitive.

CHARACTERS

Source and execution character sets (5.2.1)

The source character set is the set of legal characters that can appear in source files. It is dependent on the chosen encoding for the source file. See *Text encodings*, page 246. By default, the source character set is Raw.

The execution character set is the set of legal characters that can appear in the execution environment. These are the execution character set for character constants and string literals and their encoding types:

Execution character set	Encoding type
`L`	UTF-32
`u`	UTF-16
`U`	UTF-32
`u8`	UTF-8
`none`	The source character set

Table 53: Execution character sets and their encodings

The DLIB runtime environment needs a multibyte character scanner to support a multibyte execution character set. See *Locale*, page 157.

Bits per character in execution character set (5.2.4.2.1)

The number of bits in a character is represented by the manifest constant `CHAR_BIT`. The standard include file `limits.h` defines `CHAR_BIT` as 8.

Mapping of characters (6.1.3.4)

The mapping of members of the source character set (in character and string literals) to members of the execution character set is made in a one-to-one way. In other words, the same representation value is used for each member in the character sets except for the escape sequences listed in the ISO standard.

Unrepresented character constants (6.1.3.4)

The value of an integer character constant that contains a character or escape sequence not represented in the basic execution character set or in the extended character set for a wide character constant generates a diagnostic message, and will be truncated to fit the execution character set.

Character constant with more than one character (6.1.3.4)

An integer character constant that contains more than one character will be treated as an integer constant. The value will be calculated by treating the leftmost character as the most significant character, and the rightmost character as the least significant character, in an integer constant. A diagnostic message will be issued if the value cannot be represented in an integer constant.

A wide character constant that contains more than one multibyte character generates a diagnostic message.

Converting multibyte characters (6.1.3.4)

See *Locale*, page 157.

Range of 'plain' char (6.2.1.1)

A ‘plain’ `char` has the same range as an `unsigned char`.

INTEGERS

Range of integer values (6.1.2.5)

The representation of integer values are in the two's complement form. The most significant bit holds the sign—1 for negative, 0 for positive and zero.

See *Basic data types—integer types*, page 328, for information about the ranges for the different integer types.

Demotion of integers (6.2.1.2)

Converting an integer to a shorter signed integer is made by truncation. If the value cannot be represented when converting an unsigned integer to a signed integer of equal length, the bit-pattern remains the same. In other words, a large enough value will be converted into a negative value.

Signed bitwise operations (6.3)

Bitwise operations on signed integers work the same way as bitwise operations on unsigned integers—in other words, the sign-bit will be treated as any other bit, except for the operator >> which will behave as an arithmetic right shift.

Sign of the remainder on integer division (6.3.5)

The sign of the remainder on integer division is the same as the sign of the dividend.

Negative valued signed right shifts (6.3.7)

The result of a right-shift of a negative-valued signed integral type preserves the sign-bit. For example, shifting `0xFF00` down one step yields `0xFF80`.

FLOATING POINT

Representation of floating-point values (6.1.2.5)

The representation and sets of the various floating-point numbers adheres to IEC 60559. A typical floating-point number is built up of a sign-bit (`s`), a biased exponent (`e`), and a mantissa (`m`).

See *Basic data types—floating-point types*, page 332, for information about the ranges and sizes for the different floating-point types: `float` and `double`.

Converting integer values to floating-point values (6.2.1.3)

When an integral number is cast to a floating-point value that cannot exactly represent the value, the value is rounded (up or down) to the nearest suitable value.

Demoting floating-point values (6.2.1.4)

When a floating-point value is converted to a floating-point value of narrower type that cannot exactly represent the value, the value is rounded (up or down) to the nearest suitable value.

ARRAYS AND POINTERS

size_t (6.3.3.4, 7.1.1)

See *size_t*, page 334, for information about `size_t`.

Conversion from/to pointers (6.3.4)

See *Casting*, page 334, for information about casting of data pointers and function pointers.

ptrdiff_t (6.3.6, 7.1.1)

See *ptrdiff_t*, page 335, for information about the `ptrdiff_t`.

REGISTERS

Honoring the register keyword (6.5.1)

User requests for register variables are not honored.

STRUCTURES, UNIONS, ENUMERATIONS, AND BITFIELDS

Improper access to a union (6.3.2.3)

If a union gets its value stored through a member and is then accessed using a member of a different type, the result is solely dependent on the internal storage of the first member.

Padding and alignment of structure members (6.5.2.1)

See the section *Basic data types—integer types*, page 328, for information about the alignment requirement for data objects.

Sign of 'plain' bitfields (6.5.2.1)

A 'plain' `int` bitfield is treated as a `signed int` bitfield. All integer types are allowed as bitfields.

Allocation order of bitfields within a unit (6.5.2.1)

Bitfields are allocated within an integer from least-significant to most-significant bit.

Can bitfields straddle a storage-unit boundary (6.5.2.1)

Bitfields cannot straddle a storage-unit boundary for the chosen bitfield integer type.

Integer type chosen to represent enumeration types (6.5.2.2)

The chosen integer type for a specific enumeration type depends on the enumeration constants defined for the enumeration type. The chosen integer type is the smallest possible.

QUALIFIERS

Access to volatile objects (6.5.3)

Any reference to an object with volatile qualified type is an access.

DECLARATORS

Maximum numbers of declarators (6.5.4)

The number of declarators is not limited. The number is limited only by the available memory.

STATEMENTS

Maximum number of case statements (6.6.4.2)

The number of case statements (case values) in a switch statement is not limited. The number is limited only by the available memory.

PREPROCESSING DIRECTIVES

Character constants and conditional inclusion (6.8.1)

The character set used in the preprocessor directives is the same as the execution character set. The preprocessor recognizes negative character values if a 'plain' character is treated as a `signed` character.

Including bracketed filenames (6.8.2)

For file specifications enclosed in angle brackets, the preprocessor does not search directories of the parent files. A parent file is the file that contains the `#include` directive. Instead, it begins by searching for the file in the directories specified on the compiler command line.

Including quoted filenames (6.8.2)

For file specifications enclosed in quotes, the preprocessor directory search begins with the directories of the parent file, then proceeds through the directories of any grandparent files. Thus, searching begins relative to the directory containing the source file currently being processed. If there is no grandparent file and the file is not found, the search continues as if the filename was enclosed in angle brackets.

Character sequences (6.8.2)

Preprocessor directives use the source character set, except for escape sequences. Thus, to specify a path for an include file, use only one backslash:

```
#include "mydirectory\myfile"
```

Within source code, two backslashes are necessary:

```
file = fopen("mydirectory\\myfile","rt");
```

Recognized pragma directives (6.8.6)

In addition to the pragma directives described in the chapter *Pragma directives*, the following directives are recognized and will have an indeterminate effect. If a pragma directive is listed both in the chapter *Pragma directives* and here, the information provided in the chapter *Pragma directives* overrides the information here.

```
alignment

baseaddr

basic_template_matching

building_runtime

can_instantiate

codeseg

cspy_support

define_type_info

do_not_instantiate

early_dynamic_initialization

function

function_effects

hdrstop

important_typedef

instantiate

keep_definition

library_default_requirements

library_provides

library_requirement_override
```

`memory`

`module_name`

`no_pch`

`once`

`system_include`

`warnings`

Default __DATE__ and __TIME__ (6.8.8)

The definitions for `__TIME__` and `__DATE__` are always available.

LIBRARY FUNCTIONS FOR THE IAR DLIB RUNTIME ENVIRONMENT

Note: Some items in this list only apply when file descriptors are supported by the library configuration. For more information about runtime library configurations, see the chapter *The DLIB runtime environment*.

NULL macro (7.1.6)

The `NULL` macro is defined to `0`.

Diagnostic printed by the assert function (7.2)

The `assert()` function prints:

`filename``:`*`linenr expression`* `-- assertion failed`

when the parameter evaluates to zero.

Domain errors (7.5.1)

`NaN` (Not a Number) will be returned by the mathematic functions on domain errors.

Underflow of floating-point values sets errno to ERANGE (7.5.1)

The mathematics functions set the integer expression `errno` to `ERANGE` (a macro in `errno.h`) on underflow range errors.

fmod() functionality (7.5.6.4)

If the second argument to `fmod()` is zero, the function returns `NaN`—`errno` is set to `EDOM`.

signal() (7.7.1.1)

The signal part of the library is not supported.

Note: The default implementation of `signal` does not perform anything. Use the template source code to implement application-specific signal handling. See *signal*, page 154 and *raise*, page 152, respectively.

Terminating newline character (7.9.2)

`stdout` stream functions recognize either `newline` or `end of file (EOF)` as the terminating character for a line.

Blank lines (7.9.2)

Space characters written to the `stdout` stream immediately before a newline character are preserved. There is no way to read the line through the `stdin` stream that was written through the `stdout` stream.

Null characters appended to data written to binary streams (7.9.2)

No null characters are appended to data written to binary streams.

Files (7.9.3)

Whether the file position indicator of an append-mode stream is initially positioned at the beginning or the end of the file, depends on the application-specific implementation of the low-level file routines.

Whether a write operation on a text stream causes the associated file to be truncated beyond that point, depends on the application-specific implementation of the low-level file routines. See *Briefly about input and output (I/O)*, page 124.

The characteristics of the file buffering is that the implementation supports files that are unbuffered, line buffered, or fully buffered.

Whether a zero-length file actually exists depends on the application-specific implementation of the low-level file routines.

Rules for composing valid file names depends on the application-specific implementation of the low-level file routines.

Whether the same file can be simultaneously open multiple times depends on the application-specific implementation of the low-level file routines.

remove() (7.9.4.1)

The effect of a remove operation on an open file depends on the application-specific implementation of the low-level file routines. See *Briefly about input and output (I/O)*, page 124.

rename() (7.9.4.2)

The effect of renaming a file to an already existing filename depends on the application-specific implementation of the low-level file routines. See *Briefly about input and output (I/O)*, page 124.

%p in printf() (7.9.6.1)

The argument to a `%p` conversion specifier, print pointer, to `printf()` is treated as having the type `void *`. The value will be printed as a hexadecimal number, similar to using the `%x` conversion specifier.

%p in scanf() (7.9.6.2)

The `%p` conversion specifier, scan pointer, to `scanf()` reads a hexadecimal number and converts it into a value with the type `void *`.

Reading ranges in scanf() (7.9.6.2)

A - (dash) character is always treated as a range symbol.

File position errors (7.9.9.1, 7.9.9.4)

On file position errors, the functions `fgetpos` and `ftell` store `EFPOS` in `errno`.

Message generated by perror() (7.9.10.4)

The generated message is:

`usersuppliedprefix``:`*`errormessage`*

Allocating zero bytes of memory (7.10.3)

The `calloc()`, `malloc()`, and `realloc()` functions accept zero as an argument. Memory will be allocated, a valid pointer to that memory is returned, and the memory block can be modified later by `realloc`.

Behavior of abort() (7.10.4.1)

The `abort()` function does not flush stream buffers, and it does not handle files, because this is an unsupported feature.

Behavior of exit() (7.10.4.3)

The argument passed to the `exit` function will be the return value returned by the `main` function to `cstartup`.

Environment (7.10.4.4)

The set of available environment names and the method for altering the environment list is described in *getenv*, page 150.

system() (7.10.4.5)

How the command processor works depends on how you have implemented the `system` function. See *system*, page 155.

Message returned by strerror() (7.11.6.2)

The messages returned by `strerror()` depending on the argument is:

Argument	Message
`EZERO`	`no error`
`EDOM`	`domain error`
`ERANGE`	`range error`
`EFPOS`	`file positioning error`
`EILSEQ`	`multi-byte encoding error`
`<0 || >99`	`unknown error`
all others	`error` *nnn*

Table 54: Message returned by strerror()—DLIB runtime environment

The time zone (7.12.1)

The local time zone and daylight savings time implementation is described in *__time32, __time64*, page 155.

clock() (7.12.2.1)

From where the system clock starts counting depends on how you have implemented the `clock` function. See *clock*, page 148.

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Symbols

Numerics