

# VSI C++ for OpenVMS User Guide

**Operating System and Version:** VSI OpenVMS IA-64 Version 8.4-1H1 or higher  
VSI OpenVMS Alpha Version 8.4-2L1 or higher  
VSI OpenVMS x86-64 Version 9.2-1 or higher

**Software Version:** VSI C++ Version 7.4-6 for OpenVMS IA-64  
VSI C++ Version 7.4-8 for OpenVMS Alpha  
VSI C++ Version 7.4-8 for OpenVMS x86-64

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# VSI C++ for OpenVMS User Guide



VMS Software

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# Preface

This manual contains information about developing and debugging VSI C++ programs on OpenVMS systems, and includes information on other OpenVMS features and tools that work with the compiler.

## 1. About VSI

VMS Software, Inc. (VSI) is an independent software company licensed by Hewlett Packard Enterprise to develop and support the OpenVMS operating system.

## 2. Intended Audience

This manual is intended for experienced programmers who need to develop VSI C++ programs on OpenVMS systems. Users of this manual should have a basic understanding of the C++ language and some familiarity with the Digital Command Language (DCL).

## 3. Document Structure

This manual is organized as follows:

- *Chapter 1, "Building and Running C++ Programs"* shows how to create, compile, link, and run VSI C++ programs.
- *Chapter 2, "VSI C++ Implementation"* describes features and characteristics that are specific to the VSI C++ implementation.
- *Chapter 3, "C++ Language Environment"* describes guidelines and procedures for customizing your language environment.
- *Chapter 4, "Porting Applications to IA-64 Systems"* describes how to make code used with other C++ implementations acceptable to the VSI C++ compiler.
- *Chapter 6, "Using Templates"* describes how to use templates with VSI C++.
- *Chapter 7, "Handling C++ Exceptions"* explains how to use C++ exception handling.
- *Chapter 8, "The C++ Standard Library"* describes the VSI C++ implementation of the C++ Standard Library.
- *Chapter 9, "Using the OpenVMS Debugger"* explains how to use the OpenVMS Debugger with VSI C++.
- *Chapter 10, "Using 64-bit Address Space"* explains how to use 64-bit address space.
- *Appendix A, "Compiler Command Qualifiers"* describes compiler command qualifiers.
- *Appendix B, "Built-In Functions"* describes built-in functions.
- *Appendix C, "Class Library Restrictions (Alpha and IA-64 only)"* describes Class Library restrictions.

## 4. Related Documents

The following documents contain information associated with topics in this manual:

- *VSI C++ Class Library Reference Manual*

This manual describes a library of VSI C++ classes.

- *VSI C++ Installation Guide for OpenVMS Alpha*

This document supplies the information necessary to install VSI C++ on OpenVMS Alpha systems.

- *VSI C++ Installation Guide for OpenVMS I64*

This document supplies the information necessary to install VSI C++ on OpenVMS IA-64 systems.

- *VSI C++ Installation Guide for OpenVMS x86-64* [<https://docs.vmssoftware.com/vsi-c++-for-openvms-x86-installation-guide/>]

This document supplies the information necessary to install VSI C++ on OpenVMS x86-64 systems.

- *VSI C Run-Time Library Reference Manual for OpenVMS Systems* [<https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/>]

This library manual provides information, useful to VSI C++ users, on the OpenVMS Run-Time Library (RTL) for C functions and macros, which include the ANSI C standard library. This manual also contains information about porting programs to and from other operating systems.

*The Annotated C++ Reference Manual* is available only in printed form. Online copies are not available.

- <https://en.cppreference.com/w/cpp/links>

Lists the C++ standards.

## 5. VSI Encourages Your Comments

You may send comments or suggestions regarding this manual or any VSI document by sending electronic mail to the following Internet address: <docinfo@vmssoftware.com>. Users who have VSI OpenVMS support contracts through VSI can contact <support@vmssoftware.com> for help with this product.

## 6. OpenVMS Documentation

The full VSI OpenVMS documentation set can be found on the VMS Software Documentation webpage at <https://docs.vmssoftware.com>.

## 7. Platform Labels

This guide contains information applicable to the VSI OpenVMS operating system. The information in this guide applies to both of these processors, except when specifically labeled as follows:

Alpha only	Specific to the OpenVMS operating system running on an Alpha processor.
IA-64 only	Specific to the OpenVMS operating system running on an IA-64 processor. On this platform, the product name of the operating system is OpenVMS for Industry Standard 64 for Integrity servers (abbreviated in this manual as OpenVMS I64 or I64).

x86-64 only	Specific to the OpenVMS operating system running on an x86-64 processor.
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## 8. Conventions

The conventions found in the following table are used in this document.

Convention	Meaning
<code>class complex {     .     .     . };</code>	A vertical ellipsis indicates that some intervening program code or output is not shown. Only the more pertinent material is shown in the example.
<code>, ...</code>	A horizontal ellipsis in a syntax description indicates that you can enter additional parameters, options, or values. A comma preceding the ellipsis indicates that successive items must be separated by commas.
<code>The complex class ... The get() function ...</code>	Monospaced type denotes the names of VSI C++ language elements, and also the names of classes, members, and nonmembers. Monospaced type is also used in text to reference code elements displayed in examples.
<i>italic</i>	Italic type denotes the names of variables that appear as parameters or in arguments to functions.
<b>boldface</b>	Boldface type in text indicates the first instance of terms defined in text.
UPPERCASE, lowercase	UNIX operating system differentiates between uppercase and lowercase characters. Literal strings that appear in examples, syntax descriptions, and function definitions must be typed exactly as shown.
◆	This symbol indicates the end of information applicable exclusively to a specified architecture.

## 9. New and Changed Features in C++ IA-64 Version 7.2

Some of the new or changed features supported by this version of the compiler are:

- 64-bit pointer support is added for C++ IA-64.

This support is compatible with the 64-bit pointer support in the C++ and C compilers for OpenVMS Alpha. It supports the same `/POINTER_SIZE` command-line qualifier, the `__INITIAL_POINTER_SIZE` predefined macro, and the same pragmas (`#pragma pointer_size` and `#pragma required_pointer_size`). Please see the V7.2 release notes for more information on 64-bit pointer support for the IA-64 compiler.

- Variadic macros are now supported.

This feature allows macros to take a variable number of arguments. It was added to VSI C Version 6.4 and is supported by a number of other C and C++ compilers. This feature is available only when the value of the `/STANDARD` qualifier is `RELAXED` (the default), `MS`, or `GNU`.

- Support is added for generation of a new section type in the object file that maps mangled names to their original unmangled form.

Future versions of the linker will take advantage of this feature by using the demangled spelling of an identifier name for its error messages. In addition, the linker will be able to generate a new section in the linker map that shows mangled names and their corresponding unmangled original name.

- Prologue and epilogue file header processing is now supported in VSI C++.
- The `__FUNCTION__` identifier is added.

`__FUNCTION__` is a predefined pointer to char defined by the compiler, which points to the name of the function as it appears in the source program. `__FUNCTION__` is same as `__func__` of C99.

## 10. New and Changed Features in C++ Version 7.1

C++ Version 7.1 runs on OpenVMS Alpha and OpenVMS IA-64 servers. The compiler behaves much the same on both systems, with some differences, primarily in the support for built-in functions, default floating-point representation, and predefined macros. These differences are noted in the relevant sections of this manual.

Some of the new or changed features supported by this version of the compiler on both Alpha and IA-64 systems are:

- `cname` header support is added (*Section 3.1, "cname Headers"*).

The C++ compiler implements section 17.4.1.2 - Headers [lib.headers] "C++ Headers for C Library Facilities" of the *C++ Standard*.

The implementation consists of 18 `<cname>` headers defined in the Standard (*Chapter 3, "C++ Language Environment"*). As required by the C++ standard, the `<cname>` headers define C names in the `std` namespace.

The `/[NO]PURE_CNAME` qualifier is added to control insertion of the names by `<cname>` headers into the `std` namespace only (`/PURE_CNAME`), or into the `std` namespace and the global namespace (`/NOPURE_CNAME`).

- The `/[NO]FIRST_INCLUDE=(file[,...])` qualifier is added (see *Appendix A, "Compiler Command Qualifiers"* for the detailed description).

This qualifier includes the specified files before any source files. It corresponds to the *UNIX* `-FI` switch.

- The `#pragma include_directory` preprocessor directive is added (*Section 2.1.1.7, "#pragma include\_directory Directive"*).

This pragma is intended to ease DCL command-line length limitations when porting applications from POSIX-like environments built with makefiles containing long lists of `-I` options that specify directories to search for headers.

- Changes are made to the `/WARNING` qualifier and compiler messages (*Section 2.5, "Message Control and Information Options"*).

Changes to the `/WARNINGS` qualifier include bug fixes and improved compatibility with the C compiler. Some changes that might affect user compilations are:

- The `/WARNINGS=ENABLE=ALL` qualifier now enables all compiler messages including informational-level messages.
- The `/WARNINGS=INFORMATIONALS` qualifier continues to enable most informationals, but we recommend that `/WARNINGS=ENABLE=ALL` be used instead
- Using `/WARNINGS=INFORMATIONALS=<tag>` no longer enables all other informational messages.

Also, some compiler diagnostics might be different on Alpha and IA-64 systems, and some conditions detected on one platform might not be detected on the other.

- A new C++ front end is added to provide improved conformance to the C++ International Standard.
- Support for `/STANDARD=CFRONT` is retired.





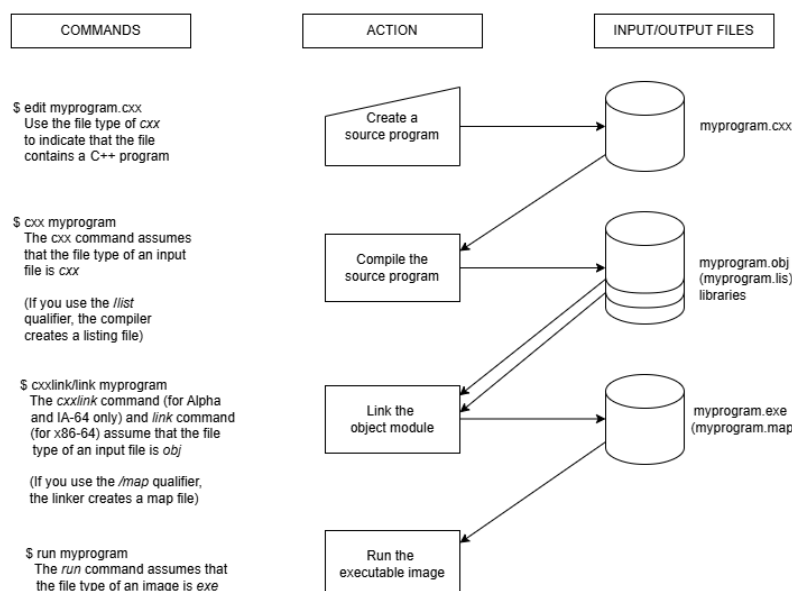
# Chapter 1. Building and Running C++ Programs

**IA-64 only:** C++ is an evolving language in which new features have recently replaced outmoded constructs. The C++ Standard Library provided with this release defines a complete specification of the C++ International Standard, with some differences, as described in the online release notes in:

`SYS$HELP:CXX_RELEASE_NOTES`

This chapter provides information about basic steps in developing a C++ program on an OpenVMS system. These steps are shown in *Figure 1.1, "Steps in Developing a C++ Program"*.

**Figure 1.1. Steps in Developing a C++ Program**



To create and modify a C++ program, you must invoke a text editor. The OpenVMS system provides you with at least two text editors: VAX EDT (EDT) and the VSI Text Processing Utility (DECTPU). Another editor that you can use is the VSI Language-Sensitive Editor (LSE), which is sold separately. Use `.cxx` as the file type to signify that you are creating a C++ source program.

When you compile your program with the `cxx` command, you do not have to specify the file type; by default, C++ first looks for files with the `.cxx` type.

If the compilation succeeds, the compiler creates an object file with the type `.obj`. If the compiler detects errors, the system displays each error detected. You then reinvoke a text editor to make corrections.

When your program compiles successfully, you use the CXXLINK facility for Alpha and IA-64 only and the LINK facility for x86-64 to create an executable image. Compiler and linker commands both take qualifiers, as described in *Section 1.2, "Using the Compiler"* and *Section 1.3, "Linking a Program (Alpha only)"*.

When you have an executable image file, use the `run` command, or define a foreign command, to run your program. See *Section 1.6, "Running a C++ Program"* for more information on running image files.

## 1.1. Using the DECTPU Text Editor

With DECTPU, you have a choice of two editing interfaces, the Extensible Versatile Editor (EVE) or the DECTPU EDT Keypad Emulator. You can also create your own interfaces with DECTPU. At any time during your editing session you have access to online help.

When you invoke DECTPU to create a file, the editor automatically creates a journal file, which you can use to recover your keyboard entries if the system fails during an editing session. To initiate recovery, use the following command format:

```
edit/tpu/recover file-spec
```

The interactive editor interface, EVE, responds to all the common editing functions, invoked using the editing keypad, and supports more advanced functions that you type as commands on the EVE command line. For more information on using EVE, see the Guide to VMS Text Processing.

## 1.2. Using the Compiler

The compiler detects source program errors and shows each error either in a screen display or in the batch log file, depending on whether you run the compiler interactively or in batch mode. If the compilation succeeds, the compiler generates machine-language instructions from the source statements, and groups these instructions into an object module for the linker.

The compiler command `cxx` has the following format:

```
cxx[/qualifier...][ file-spec [/qualifier...]],...
```

You use qualifiers to instruct the compiler to perform some action. A qualifier placed immediately after the CXX command affects all the files listed. A qualifier placed immediately after a file specification affects only the preceding file, unless you concatenate your files. A qualifier placed on an individual file specification overrides a qualifier placed immediately after the CXX command.

If you include more than one file specification on the same line, use commas (,) or plus signs (+) as separators. For example:

```
$ cxx/list prog_1, prog_2, prog_3
```

A comma instructs the compiler to keep source files separate and to create an object file and a listing file for each source file. A plus sign instructs the compiler to concatenate each of the specified source files, and to create one object file and one listing file. Any qualifier specified for one file within a list of concatenated files affects all these files.

---

### Note

Comma lists are not supported on IA-64 systems. Their use causes a fatal error.

OpenVMS x86-64 C++ does not support comma-separated list for source files, it accepts only single source file at a time. When using a list, compiler issues a warning and does nothing.

---

### 1.2.1. Compiler Command Qualifiers

For a complete description of command line qualifiers, refer to *Appendix A, "Compiler Command Qualifiers"* or to the online HELP.

## 1.2.2. Compiler Error Messages

If the compiler detects errors in your source code, the compiler signals these errors by displaying diagnostic messages in the following format:

```
%CXX-s-ident, message-text
                at line number n in file name
```

Where:

**s**

Is the error severity, represented as follows:

F	Fatal error. The compiler stops immediately without producing an object file. You cannot link the program until you correct this error.
E	Error. The compiler proceeds, and possibly generates other messages, but does not produce an object file. You cannot link the program until you correct this error.
W	Warning. The compiler takes some corrective action and produces an object file. However, to avoid unexpected results you must verify that the compiler's action is what you wanted.
I	Information. The compiler informs you of specific actions taken. You need not take any action yourself regarding this message.
S	Success.

**ident**

Is a mnemonic (abbreviation) of the message text.

**message-text**

Is the full text of a compiler diagnostic message explaining what happened.

**n**

Is an integer that gives you the number of the line where the error occurs. The number is relative to the beginning of the file or module in which the error occurs. The number appears on your terminal but not in listing files.

**name**

Is the name of the file or module in which the error occurs. The name appears on your terminal but not in listing files.

To be sure your program runs successfully, examine the diagnostic messages, evaluate error severity, and make any necessary corrections.

You can suppress certain information and warning diagnostic messages using the `#pragma message` preprocessor directive. For information about this directive, see *Section 2.1.1.11, "#pragma message Directive"*.

## 1.3. Linking a Program (Alpha only)

This section describes how to link a C++ program on OpenVMS Alpha systems.

After your program or module successfully compiles, you **must** use the CXXLINK facility to combine your object modules into one executable image.

The CXXLINK facility is layered on the OpenVMS Linker utility and provides the ability to link your C++ application. Besides linking your C++ application, the CXXLINK facility completes the automatic

template instantiation process; see *Chapter 6, "Using Templates"* for details. CXXLINK also ensures that the Standard Template Library run-time support and the exception handling run-time support are linked into your application as needed.

CXXLINK uses the same command line format that you would use to invoke the OpenVMS Linker utility; thus, you can simply replace the LINK verb with CXXLINK in your command procedures. The CXXLINK command has the following format:

```
CXXLINK[/command-qualifier]... {file-spec[/file-qualifier...]},...
```

If you include more than one input file specification, use commas or plus signs as separators. By default, the linker creates an output file with the same name as the first input file and the file type *.exe*. If you want the output file to take the name of your main program, be sure to specify your main program file first. You can also use the */EXECUTABLE=name.exe* qualifier on the CXXLINK command line to specify a name for the executable image.

Do not use the linker *cluster=* option to reference OpenVMS object modules that define global static objects. Using this option prevents the constructors and destructors for global static objects from being run during image activation and exit.

---

## Caution

The OpenVMS Linker expects a function whose identifier is *main*. If a C++ program lacking a definition of *main* is inadvertently linked, then program execution begins at the first function seen by the linker.

---

## 1.3.1. CXXLINK Interactions with OpenVMS Linker Qualifiers

CXXLINK makes use of the OpenVMS Linker Utility's LNK\$LIBRARY logical names to specific object libraries as input to the linker. If the CXXLINK command includes the */USERLIBRARY* qualifier in any form, an informational message will be displayed and CXXLINK will list any required object libraries in a linker options file.

### 1.3.1.1. Command Parameters and Qualifier

In addition to the following qualifiers, the CXXLINK command accepts the same parameters and qualifiers as the OpenVMS Linker utility (see *Section 1.3.5, "Linker Command Qualifiers"* for some of the more useful OpenVMS Linker qualifiers). CXXLINK-specific qualifiers are stripped off prior to calling the OpenVMS Linker utility and therefore have no effect on default device or directory specifications applied by the OpenVMS Linker facility.

Command Qualifiers	Defaults
<i>/[NO]LOG_FILE[=filename]</i>	<i>/NOLOG_FILE</i>
<i>/PREINST</i>	<i>/PREINST</i>
<i>/PRELINK=(option[,option2])</i>	See HELP.
<i>/REPOSITORY=(writeable-repository[,readonly-repository,...])</i>	See HELP.
<i>/USE_LINK_INPUT[=filename]</i>	<i>/NOUSE_LINK_INPUT</i>
<i>/VERSION</i>	None.

For more information about CXXLINK qualifiers and parameters, type `HELP CXXLINK`.

## 1.3.2. Migrating from LINK to CXXLINK

Because a single CXXLINK command can invoke the OpenVMS Linker utility multiple times, you must not specify user mode (`DEFINE/USER_MODE`) logical names. If CXXLINK executes a second LINK command, the original `DEFINE/USER_MODE` logical name is not retained for that second command. Incorrect results can occur.

You should check command procedures that perform link operations of code generated by the C++ compiler for any `/USER_MODE` logical names that are intended to be in effect during a LINK operation. If you find any, you can modify the procedures CXXLINK in one of the following ways:

- Define the logical name without `/USER_MODE`. This means that the logical name should be deassigned, or its previous value reassigned, after the CXXLINK operation is completed to ensure that prior state is restored. Any `ON ERROR` cases that may be jumped to if the CXXLINK fails should check for and deassign or reassign the logical name if needed.
- Move the definition(s) into a separate command procedure. CXXLINK checks the logical name `CXX$LINK_INIT`, and if it is defined, executes the command procedure in its subprocess prior to executing any LINK command.

Consider the following procedure:

```
$ DEFINE/USER MYLIB MYAREA:MYLIB.OLB
$ LINK A,B,SYS$INPUT:/OPT
MYLIB/LIB
$
```

To have the procedure work with CXXLINK, modify it as follows:

```
$ CREATE CXX$LINK_INIT.COM
$ DEFINE MYLIB MYAREA:MYLIB.OLB
$EOD
$ DEFINE/USER CXX$LINK_INIT SYS$DISK:[ ]CXX$LINK_INIT.COM
$ LINK A,B,SYS$INPUT:/OPT
MYLIB/LIB
$!
$ DELETE CXX$LINK_INIT.COM;
```

Note that the `CXX$LINK_INIT` command procedure defines MYLIB without the `/USER_MODE` qualifier. This is because the command procedure is executed only once in the spawned process.

## 1.3.3. Linking to the C++ Standard Library

When you compile and link programs that use the C++ Standard Library, no special qualifiers are required. The C++ driver automatically includes the Standard Library run-time support on the link command, and automatic template instantiation is the default mode.

For example, to build a program called `prog.cxx` that uses the Standard Library, you enter the following command:

```
$ CXX prog.cxx
```

For detailed information about the Standard Library, refer to *Chapter 8, "The C++ Standard Library"*.

## 1.3.4. Linking to the C++ Class Library

Reusing code is a cornerstone of object-oriented programming. To minimize the time it takes to develop new applications, a set of reusable classes is an essential part of the VSI C++ compiler environment. Class libraries offer a variety of predefined classes that enable you to work more efficiently.

For a detailed explanation of the class library packages supplied with the compiler, see the *VSI C++ Class Library Reference Manual*, CXX\_CLASSLIB.PS, in the SYS\$COMMON:[SYSHLP.CXX\$HELP] directory.

The Class Library has always been provided in shareable image format. The Class Library is also provided in object library format.

Using the Class Library as an object library provides a functional advantage over using the shareable image. When your program redefines the global `new` and `delete` operators and uses the Class Library object library, the `new` and `delete` calls within the Class Library are directed to the `new` and `delete` operators defined by your program. On the other hand, when your program uses the Class Library shareable image, the `new` and `delete` calls within the Class Library always call the standard `new` and `delete` operators. Linking with the shareable image is the default method.

When you use the Class Library as a shareable image, the Class Library code resides in an image file in SYS\$SHARE and is shared by all C++ programs. This process has the advantages of: reducing the size of a program's executable image, decreasing the amount of disk space taken up by the program's image, and letting your program swap in and out of memory faster because of decreased size.

### 1.3.4.1. Linking Against the Class Library Object Library

To link against the Class Library object library, you need to specify the `/NOSYSSHR` qualifier on your CXXLINK command. For example:

```
$ CXXLINK/NOSYSSHR my_program.obj
```

If your program defines nonlocal static objects whose constructors or destructors use any part of the Class Library, you need to ensure that the Class Library is initialized before your objects' constructors are invoked. (Note that this is not an issue when you link against the Class Library shareable image.) To guarantee this order of initialization, specify the Class Library initialization object module CXXL\_INIT as the first module in your CXXLINK command. To do this, use a CXXLINK command similar to the following:

```
$ CXXLINK/NOSYSSHR/EXE=my_program SYS$SHARE:STARLET.OLB -  
_ $ /INCLUDE=CXXL_INIT, my_program.obj
```

If your program uses the task package, you must explicitly include the CMA shared library when you link `/NOSYSSHR`, as in the following example:

```
$ CXXLINK/NOSYSSHR my_program.obj, SYS$INPUT:/OPT -  
_ $ SYS$SHARE:CMA$LIB_SHR/SHARE  
^Z
```

### 1.3.4.2. Linking Against the Class Library Shareable Image

No special action is needed to link with the Class Library; simply specify the object modules and object libraries that you want to link. The linker automatically finds and resolves any references to objects in the Class Library when it searches the system-supplied shareable image library, SYS\$LIBRARY:IMAGELIB.OLB.

## 1.3.5. Linker Command Qualifiers

You can use qualifiers to modify OpenVMS Linker output and to invoke debugging and traceback facilities. The following list shows some of the most useful LINK command qualifiers that you can specify on your CXXLINK command. For a full discussion of the OpenVMS Linker, see the *VSI OpenVMS Linker Utility* manual.

Command Qualifiers	Defaults
/BRIEF	None.
/[NO]CROSS_REFERENCE	/NOCROSS_REFERENCE
/[NO]DEBUG	/NODEBUG
/[NO]EXECUTABLE[=file-spec]	/EXECUTABLE=first-object-file-name.exe
/FULL	None.
/[NO]MAP	/NOMAP (interactive) /MAP (batch)
/[NO]SHAREABLE	/NOSHAREABLE
/[no]TRACEBACK	/TRACEBACK

## 1.3.6. Linker Error Messages

If the OpenVMS Linker detects errors while linking object modules, the linker displays messages indicating the cause and severity of error. Because CXXLINK uses the OpenVMS Linker to link your C++ program, CXXLINK displays these linker messages. The linker does not produce an image file if errors or fatal errors occur (conditions with severities of E or F).

Some problems that commonly occur during linking are as follows:

- You try to link a program without defining every function that the program calls.

The linker responds by issuing warnings. For example:

```
%LINK-W-USEUNDEF symbol-name
```

A symbol name that you do not recognize could be a **mangled** name. Name mangling is the mechanism that the compiler uses to encode exceptionally long identifiers, including C++ function names. By default, CXXLINK displays such symbols in their demangled form. To see a symbol in its mangled form, use the /PRELINK=NODEMANGLE qualifier on your CXXLINK command. (See *Section 1.7, "Name Demangling"* for more information about name demangling.)

- You try to link a module that had warning or error messages during compilation.

To avoid unexpected results, verify that the linker's action is acceptable.

- You try to link a nonexistent module.

Check to see if the module exists (in the directory or library you expect it to be in) and is spelled correctly.

- You redefine a C RTL function, or override the global operators `new` or `delete`. For more information, see the /[NO]PREFIX\_LIBRARY\_ENTRIES Qualifier in *Section 1.2.1, "Compiler Command Qualifiers"*.

For an explanation of linker messages, invoke the HELP/MESSAGE utility.

## 1.4. Linking a Program (IA-64 only)

This section describes how to link a C++ program on OpenVMS IA-64 systems.

After your program or module successfully compiles, you must use either the CXXLINK facility or OpenVMS Linker to combine your object modules into one executable image.

The CXXLINK facility is layered on the OpenVMS Linker utility and provides the ability to link your C++ application. On IA-64 systems, the CXXLINK facility accepts the same command qualifiers as CXXLINK on Alpha systems, including the full range of the Linker's command qualifiers that the CXXLINK facility passes to the Linker. For a description of Linker commands, see the *VSI OpenVMS Linker Utility* manual.

CXXLINK and LINK are functionally identical. CXXLINK is provided to allow command files from Alpha to be used on IA-64 without extra modification.

The demangler database is a file created by the compiler. By default, it is created in a [.CXX\_REPOSITORY] subdirectory of the current directory. For both the C++ compiler and CXXLINK, the location of the repository is controlled by the /REPOSITORY qualifier. For CXXLINK to correctly translate mangled names to their original, non-mangled counterparts, it is important to use the same repository for both compiling and linking.

Do not use the Linker CLUSTER= option to reference OpenVMS object modules that define global static objects. Using this option prevents the constructors and destructors for global static objects from being run during image activation and exit.

---

### Caution

The OpenVMS Linker expects a function whose identifier is `main`. If a C++ program lacking a definition of `main` is inadvertently linked, then program execution begins at the first function seen by the linker.

---

### 1.4.1. Linking Against C++ Class and Standard Library Shareable Images

On IA-64 systems, the C++ Class and Standard Library, as well as the language run-time support library, are delivered as system shareable images in SYS\$LIBRARY:

CXXL\$011\_SHR.EXE - class library image  
CXXL\$RWRTL.EXE - standard library image  
CXXL\$LANGRTL.EXE - language run-time support image

As system shareable images, these CXXL\$ images are part of the system library of shareable images, `IMAGELIB.OLB`, which is automatically searched by the Linker. Consequently, no special actions are required to link C++ applications against the class or standard library shareable image.

For example, if `PROG.CXX` uses a class from the C++ class or standard library, the following sequence of commands will compile, link, and run the program:

```
$ CXX PROG.CXX  
$ CXXL PROG.OBJ ! (or LINK PROG.OBJ)
```



```
$ RUN PROG.EXE
```

## 1.4.2. Linking Against the Object Library (Linking /NOSYSSHARE)

In addition to being delivered as system shareable images, the C++ class, standard, and language run-time support libraries are also delivered in object form in the system object library STARLET.OLB, thus making it possible to link C++ applications /NOSYSSHARE.

The C++ libraries themselves do not impose any restrictions on linking /NOSYSSHARE. However, because they are layered on top of the C Run-Time Library, the rules for linking an application that references the C Run-Time Library /NOSYSSHARE do apply.

For example, when linking /NOSYSSHARE, you must explicitly include CMA\$TIS routines in the link by either linking against the CMA\$TIS\_SHR.EXE shareable image or forcing the CMA\$TIS module from STARLET.OLB in the link. See the [VSI C Run-Time Library Reference Manual for OpenVMS Systems](https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/) [https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/] for more details.

Here are two examples of linking a C++ program /NOSYSSHARE:

```
$ CXXL/NOSYSSHARE PROG.OBJ, SYS$INPUT:/OPT
SYS$SHARE:CMA$TIS_SHR/SHARE
^Z
```

```
$ CXXL/NOSYSSHARE prog.obj, -
_.$ SYS$SHARE:STARLET.OLB/INCLUDE=CMA$TIS
```

## 1.5. Linking a Program (x86-64 only)

This section describes how to link a C++ program on OpenVMS x86-64 systems. After your program or module compiles successfully, you must use the OpenVMS Linker to combine your object modules into one executable image. For more information on Linker commands, see the *VSI OpenVMS Linker Utility Manual*.

---

### Caution

The OpenVMS Linker expects a function named **main**. If a C++ program is linked without a defined **main** function, execution will start at the first function encountered by the linker.

---

### 1.5.1. Linking Against C++ Standard Library Shareable Images

On x86-64 systems, the C++ Standard Library and standard exception classes, are delivered as system shareable images in SYS\$LIBRARY:

LIBCXX.EXE - standard library image

LIBCXXABI.EXE - exception handling support

They are part of the system library of shareable images, IMAGELIB.OLB, which is automatically searched by the Linker. Consequently, no special actions are required to link C++ applications against

the class or standard library shareable images. For example, if PROG.CXX uses a class from the C++ standard library, the following sequence of commands will compile, link, and run the program:

```
$ CXX PROG.CXX
$ LINK PROG.OBJ
$ RUN PROG.EXE
```

## 1.5.2. Linking Against the Object Library

In addition to being delivered as system shareable images, the C++ Standard libraries are also delivered in object form in SYS\$LIBRARY:

LIBCXX.OLB

LIBCXXABI.OLB

Thus, if C++ program needs to be linked against static libraries, you must provide them explicitly, or you can use the SYS\$COMMON:[SYSHLP.EXAMPLES]CXX.OPT (or SYS\$EXAMPLES:CXX.OPT) file.

For example, if PROG.CXX uses a class from the C++ standard library, the following sequence of commands will compile, link and run the program:

```
$ CXX PROG.CXX
$ LINK PROG.OBJ, SYS$EXAMPLES:CXX/OPT ! Link against static libraries
$ RUN PROG.EXE
```

## 1.6. Running a C++ Program

When your program successfully links, use the DCL RUN command to execute the image file. The RUN command has the following format:

```
RUN [/NO]DEBUG file-spec
```

**/DEBUG**

**/NODEBUG**

Determines whether you invoke the OpenVMS Debugger during run time. Use the /DEBUG qualifier to invoke the debugger if your image was not linked with the debugger. However, do not use the /DEBUG qualifier on images linked with the /NOTRACEBACK qualifier. Use the /NODEBUG qualifier if you linked your image with the /DEBUG qualifier and you do not want the debugger to prompt you. The default is RUN/DEBUG if you linked your image with the /DEBUG qualifier; otherwise, the default is RUN/NODEBUG.

For more information on debugging C++ programs, see *Chapter 9, "Using the OpenVMS Debugger"*.

### 1.6.1. Run-Time Errors

When an error occurs during program execution, the OpenVMS condition handler terminates execution and displays messages and traceback information on the currently defined sys\$error device. In the symbolic stack dump traceback message, the condition handler lists the modules that were active when the error occurred, indicating the sequence in which the modules were called.

Traceback information is available at run time only for modules compiled with /DEBUG=TRACEBACK and linked with the /TRACEBACK qualifier in effect (the default for both compiler and linker

commands). You should exclude traceback information only from thoroughly debugged program modules.

The traceback information makes reference to numbered lines that are listing lines in your program. If you include header files in the source file using the `#include` directive, the line numbers do not correspond to the source-file lines. To see the numbers that correspond to those referenced in the traceback information, generate a listing file using the `/LIST` qualifier to the compiler command.

## 1.6.2. Passing Arguments to the main Function

The `main` function in a C++ program can accept arguments from the command line from which it was invoked. The syntax for a `main` function is as follows:

```
int main(int argc,
char *argv[ ],
char *envp[ ])
{
    . . .
    return status;
}
```

In this syntax, parameter *argc* is the count of arguments present in the command line that invoked the program, and parameter *argv* is a character-string array of the arguments. Parameter *envp* is the environment array, which contains process information such as the user name and controlling terminal. Parameter *envp* has no bearing on passing command-line arguments; its primary use in C++ programs is during `exec` and `getenv` function calls. For more information, see the [VSI C Run-Time Library Reference Manual for OpenVMS Systems \[https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/\]](https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/).

In the `main` function definition, the parameters are optional. However, you can access only the parameters that you define. You can define the `main` function in any of the following ways:

```
int main()
int main(int argc)
int main(int argc, char *argv[])
int main(int argc, char *argv[], char *envp[])
```

To pass arguments to the `main` function, you can use a DCL foreign command to point to the program, or you can define the logical name `DCL$PATH` to point to an area containing the program.

To make use of `DCL$PATH` in the previous example, the resulting program executable would have to be named "echo.exe".

You can then place `echo.exe` into a specific directory and point the logical name `DCL$PATH` to it.

For example:

```
$ RENAME commarg.exe echo.exe
$ COPY echo.exe sys$login:
$ DEFINE DCL$PATH SYS$LOGIN:
```

The output would be identical to that shown in the previous example when a foreign command was used. To pass arguments to the `main` function, you must define the program as a DCL foreign command. When a program is defined and run as a foreign command, the parameter `argc` is always greater than or equal to 1, and `argv[0]` always contains the name of the image file.

The procedure for defining a foreign command involves using a DCL assignment statement to assign the name of the image file to a symbol that is later used to invoke the image. For example:

```
$ echo == "$ dsk$:commarg.exe" Return
```

The symbol `echo` is defined as a foreign command that invokes the image in `commarg.exe`. The definition of `echo` must begin with a dollar sign (\$) and include a device name.

For more information about the procedure for defining a foreign command, see the *VSI OpenVMS DCL Dictionary*.

The following example shows a C++ program called `commarg.cxx`, which displays the command-line arguments that were used to invoke it:

```
// This program echoes the command-line arguments.

#include <iostream.h>

main(int argc, char *argv[])
{
    int i;
    for (i = 0; i < argc; ++i)
        cout << i << " := >" << argv[i] << "<\n";
    return 0;
}
```

A sample output for this example is as follows:

```
$ echo Long "Day's" "Journey into Night" Return
0 := >db7:commarg.exe;1<
1 := >long<
2 := >Day's<
3 := >Journey into Night<
```

DCL converts unquoted arguments on the command line to uppercase letters. However, the C RTL internally parses the altered command line and puts all unquoted arguments back in lowercase. This makes access to arguments in VSI C++ programs compatible with C++ programs developed on other systems.

All arguments in the command line are delimited by spaces or tabs. Arguments with embedded spaces or tabs must be enclosed in quotation marks (" ").

## 1.7. Name Demangling

Because of the need to provide type-safe linking, VSI C++ encodes type information in external function names. This encoding is called **name mangling**.

Mangled names can appear in diagnostic messages from commands such as `CXXLINK/NOEXPAND` or from the OpenVMS Linker utility. To enable users to decode (or demangle) these names, the compiler provides the `CXXDEMANGLE` facility. The `CXXDEMANGLE` facility translates mangled names into the names as they originally appeared in C++ source code.

On Alpha and IA-64 systems, to do the translation, `CXXDEMANGLE` uses a data file written by the compiler during compilation. The data file contains a mapping of mangled names to their demangled forms.

On x86-64 systems, CXX\$DEMANGLE.EXE is placed in SYS\$SYSTEM. One can define a foreign command CXXDEMANGLE pointing to the image file. The syntax for the usage will be as following:

```
CXXDEMANGLE mangled-symbol-name
```

If the tool is unable to translate a mangled symbol name, it echoes the mangled symbol name.

### 1.7.1. Creating the Data File (Alpha and IA-64 only)

Each time you compile a program, the compiler stores, in a data file, all the program's external symbols in their mangled and demangled forms. If the data file does not exist, the compiler creates the data file. Otherwise, the compiler appends information to the existing data file.

You can specify the name and location of the data file using the logical name CXX\$DEMANGLER\_DB. For example, if you want your data file to be named MYCXXDB.DAT in the DISK1:[MYDIR] directory, define the CXX\$DEMANGLER\_DB logical name as follows:

```
$ DEFINE CXX$DEMANGLER_DB DISK1:[MYDIR]MYCXXDB.DAT
```

If the CXX\$DEMANGLER\_DB logical name is not defined, the compiler uses the default file name CXX\$DEMANGLER\_DB in the writeable repository. Refer to *Chapter 6, "Using Templates"* for details on how to specify the writeable repository.

### 1.7.2. Using the CXXDEMANGLE Facility (IA-64 and Alpha only)

To demangle a symbol name, CXXDEMANGLE must use the same data file as the compiler used when it compiled the program containing the symbol.

Hence, if you defined the CXX\$DEMANGLER\_DB logical name when you compiled the program, you should also define the logical name when you use the CXXDEMANGLE facility.

Similarly, if you did not define the CXX\$DEMANGLER\_DB logical name but specified the /REPOSITORY qualifier during compilation, specify the same /REPOSITORY qualifier on your CXXDEMANGLE command.

If you did not specify the /REPOSITORY qualifier on your compile command, the compiler uses the data file in the default writeable repository. To use the CXXDEMANGLE facility in this case, either issue the CXXDEMANGLE command from the same directory where the compile command was issued, or specify the appropriate /REPOSITORY qualifier on your CXXDEMANGLE command.

CXXDEMANGLE provides both a command-line interface and an interactive interface, as follows:

- To use the command-line interface, enter the CXXDEMANGLE command followed by a comma-separated list of mangled symbol names. CXXDEMANGLE then displays the demangled form of each symbol and exits. The command-line interface has the following syntax:

```
CXXDEMANGLE mangled-symbol-name [, ...]
```

The following example shows appropriate use of this syntax:

```
$ CXXDEMANGLE COPY__XPIPIPI
int * copy(int *, int *, int *)
$ CXXDEMANGLE COPY__XPPCPPCPPC, CXX$ADJCNTDFFRNCXPPP9MNS0IUE0NU
char ** copy(char **, char **, char **)
int * adjacent_difference(int *, int *, int *, minus<int >)
```

\$

If you specify a mangled symbol name using the command-line interface and the symbol contains lowercase letters, you must place the symbol within quotes. For example:

```
$ CXXDEMANGLE "MyFunction_ _xic"
```

- To use the interactive interface, enter the CXXDEMANGLE command without specifying a symbol name. CXXDEMANGLE then waits for you to enter a symbol name in its mangled form. When you enter a symbol, CXXDEMANGLE displays the demangled form of the symbol and waits for you to enter another symbol, and so forth. To exit the interactive interface, enter Ctrl/Z. The syntax for the interactive interface is as following:

```
CXXDEMANGLE
mangled-symbol-name
[...]
Ctrl/Z
```

The following example shows appropriate use of this syntax:

```
$ CXXDEMANGLE
COPY_ _XPIPIPI
int * copy(int *, int *, int *)
COPY_ _XPPCPPCPPC
char ** copy(char **, char **, char **)
CXX$ADJJCNTDFFRNCXPPP9MNS0IUE0NU
int * adjacent_difference(int *, int *, int *, minus<int >)
Ctrl/Z
$
```

When you use the interactive interface, quotes are not necessary when entering mangled symbol names that contain lowercase letters.

If CXXDEMANGLE is unable to translate a mangled symbol name, it echoes the mangled symbol name.

### 1.7.2.1. Command Qualifier (Alpha and IA-64 only)

The CXXDEMANGLE command accepts a single qualifier, /REPOSITORY.

**/REPOSITORY=(repository[,...])**

Names the repository directories that contain the data files used by CXXDEMANGLE.

The /REPOSITORY qualifier is ignored if you define the CXX\$DEMANGLER\_DB logical name. See the preceding text for details.

## 1.8. Performance Optimization Qualifiers

The following compiler qualifiers can be used to improve performance. However, they can also change behavior for nonstandard-compliant programs:

- /[NO]ANSI\_ALIAS – Specifies whether the compiler assumes the ANSI C aliasing rules to generate better optimized code. The default is /ANSI\_ALIAS.
- /ASSUME=[NO]POINTERS\_TO\_GLOBALS – Controls whether the compiler can safely assume that global variables have not had their addresses taken in code that is not visible to the current compilation. The default is /ASSUME=POINTERS\_TO\_GLOBALS.

- `/ASSUME=[NO]TRUSTED_SHORT_ALIGNMENT` – Allows the compiler additional assumptions about the alignment of `short` types that, although naturally aligned, may cross a quadword boundary. The default is `/ASSUME=NOTRUSTED_SHORT_ALIGNMENT`.
- `/ASSUME=[NO]WHOLE_PROGRAM` – Tells the compiler that except for “well-behaved library routines”, the whole program consists only of the single object module being produced by this compilation. The optimizations enabled by `/ASSUME=WHOLE_PROGRAM` include all those enabled by `/ASSUME=NOPOINTER_TO_GLOBALS` and possibly other optimizations. The default is `/ASSUME=NOWHOLE_PROGRAM`.

You can use the `/OPTIMIZE` qualifier to improve performance. This qualifier will not change application behavior.

On IA-64 systems, the floating-point formats `D_FLOAT`, `G_FLOAT`, and `F_FLOAT` are emulated using `IEEE_FLOAT`. Because this can hinder performance, using the `/FLOAT=IEEE_FLOAT` default is recommended.

See *Appendix A, "Compiler Command Qualifiers"* for detailed descriptions of these qualifiers.

## 1.9. Improving Build Performance

Partitioning a large application into several shared libraries, which are then linked into an executable, is a useful technique for reducing link times during development. See *Section 3.5, "How to Organize Your C++ Code"* for more information.

## 1.10. Deploying Your Application (Alpha only)

The VSI C++ kit contains two Run-Time Library components that you might need to redistribute with your applications:

- C++ Standard Library Object Library (LIBCXXSTD)
- C Run-Time Object Library (DECC\$CRTL.OLB)

The next sections describe the method that developers must use to redistribute Run-Time Library components to user systems. Redistribution of other components on the VSI C++ kit is prohibited. The redistribution rights set forth in the Software Product Description do not apply to the `DECC$CRTL.EXE` or `DECC$CRTL.README` files which are distributed with this kit.

### 1.10.1. Redistribution of the DECC\$CRTL.OLB Object Library

Redistribution of this library is only required by those applications which need to be linked during or after installation on an end user target system. If you link your application and ship either a shareable or executable image to your customers, then redistribution of the object library is not necessary. The linking process of your application causes those library modules to be incorporated into your resultant image.

There are two options that you can use to redistribute the `DECC$CRTL.OLB` object library. The options are based on whether the library is needed after the installation is completed.

The first option is for applications which link during installation, but have no need for the object library once installation is completed. For that set of developers, we recommend placing `DECC$CRTL.OLB` on

your kit, but to link using the copy in VMI\$KWD and not issue a `PROVIDE_FILE` option which would move this file onto the system. In other words, the object library resides only on your kit, is used during installation to link your application, but is not placed onto the end user system.

The second option is for applications which do need the object library after installation is completed. For this class of applications, the object library should be placed in a product specific location on the target system and not in `SYSS$LIBRARY`. The contents of this object library must not be inserted into the `SYSS$LIBRARY:STARLET.OLB` library.

## **1.10.2. Redistribution of the LIBCXXSTD.OLB Object Library**

Redistribution of this library is only required by those applications which need to be linked during or after installation on an end user target system. If you link your application and ship either a shareable or executable image to your customers, then redistribution of the object library is not necessary. The linking process of your application causes those library modules to be incorporated into your resultant image.

There are two options that you can be used to redistribute the `LIBCXXSTD.OLB` object library. The options are based on whether the library is needed after the installation is completed.

The first option is for applications which link during installation, but have no need for the object library once installation is completed. For that set of developers, we recommend placing `LIBCXXSTD.OLB` on your kit, but to link using the copy in VMI\$KWD and not issue a `PROVIDE_FILE` option which would move this file onto the system. In other words, the object library resides only on your kit, is used during installation to link your application, but is not placed onto the end user system.

The second option is for applications that do need the object library after installation is completed. For this class of applications, the object library should be placed in a product specific location on the target system and not in `SYSS$LIBRARY`. The contents of this object library must not be inserted into the `SYSS$LIBRARY:STARLET.OLB` library.



# Chapter 2. VSI C++ Implementation

This chapter discusses the features and characteristics specific to the VSI C++ implementation, including pragmas, predefined names, numerical limits, and other implementation-dependent aspects of the language definition.

## 2.1. Implementation-Specific Attributes

This section describes pragmas, predefined names, and limits placed on the number of characters and arguments used in C++ programs.

### 2.1.1. #pragma Preprocessor Directive

The `#pragma` preprocessor directive is a standard method for implementing features that differ from one compiler to the next. This section describes pragmas specifically implemented in the C++ compiler for OpenVMS systems.

The following `#pragma` directives are subject to macro expansion. A macro reference can occur anywhere after the `pragma` keyword.

builtins (Alpha and IA-64 only)	inline	linkage <sup>1</sup>	use_linkage <sup>1</sup>
dictionary (Alpha and IA-64 only)	noinline	module	extern_model
member_alignment	message	define_template	extern_prefix

<sup>1</sup>Not supported; specific to C

This manual displays keywords used with `#pragma` in lowercase letters. However, these keywords are not case sensitive.

#### 2.1.1.1. #pragma [no]builtins (Alpha and IA-64 only)

The `#pragma builtins` directive enables the C++ built-in functions that directly access processor instructions. If the pragma does not appear in your program, the default is `#pragma nobuiltins`.

C++ supports the `#pragma builtins` preprocessor directive for compatibility with VAX C, but it is not required.

#### 2.1.1.2. #pragma define\_template Directive (Alpha and IA-64 only)

The `#pragma define_template` directive instructs the compiler to instantiate a template with the arguments specified in the pragma. This pragma has the following syntax:

```
#pragma define_template identifier
```

For example, the following statement instructs the compiler to instantiate the template `mytempl` with the arguments `arg1` and `arg2`:

```
#pragma define_template mytempl<arg1, arg2>
```

For more information on how to use templates with the `#pragma define_template` directive, see *Section 6.2, "Manual Template Instantiation"*.

### 2.1.1.3. #pragma environment Directive (Alpha and IA-64 only)

The `#pragma environment` directive offers a way to single-handedly set, save, or restore the states of *context* pragmas. This directive protects include files from contexts set by encompassing programs and protects encompassing programs from contexts that could be set in header files that the encompassing programs include.

On OpenVMS systems, the `#pragma environment` directive affects the following pragmas:

```
#pragma member_alignment
#pragma message
#pragma extern_model
#pragma extern_prefix
```

This pragma has the following syntax:

```
#pragma environment command_line
#pragma environment header_defaults
#pragma environment restore
#pragma environment save
```

#### **command\_line**

Sets, as specified on the command line, the states of all the context pragmas. You can use this pragma to protect header files from environment pragmas that take effect before the header file is included.

#### **header\_defaults**

Sets the states of all the context pragmas to their default values. This is almost equivalent to the situation in which a program with no command line options and no pragmas is compiled; except that this pragma sets the pragma message state to `#pragma nostandard`, as is appropriate for header files.

#### **save**

Saves the current state of every pragma that has an associated context.

#### **restore**

Restores the current state of every pragma that has an associated context.

Without requiring further changes to the source code, you can use `#pragma environment` to protect header files from things like language extensions and enhancements that might introduce additional contexts.

A header file can selectively inherit the state of a pragma from the including file and then use additional pragmas as needed to set the compilation to non-default states. For example:

```
#ifdef __PRAGMA_ENVIRONMENT
#pragma __environment save ❶
#pragma __environment header_defaults ❷
#pragma member_alignment restore ❸
```

```
#pragma member_alignment save ❹
#endif

.
. /* contents of header file */
.
#ifdef __PRAGMA_ENVIRONMENT
#pragma __environment restore
#endif
```

In this example:

- ❶ Saves the state of all context pragmas
- ❷ Sets the default compilation environment
- ❸ Pops the member alignment context from the `#pragma member_alignment` stack that was pushed by `#pragma __environment save` (restoring the member alignment context to its preexisting state)
- ❹ Pushes the member alignment context back onto the stack so that the `#pragma __environment restore` can pop the entry off

Thus, the header file is protected from all pragmas, except for the member alignment context that the header file was meant to inherit.

#### 2.1.1.4. `#pragma extern_model` Directive

The `#pragma extern_model` directive controls the compiler's interpretation of data objects that have external linkage. You can use this pragma to select the global symbol model to use for externs. The default is the relaxed `refdef` model.

---

#### Note

Take great care when using the non-default `extern_model`. The main purpose of `extern_model` is to allow C++ to share global data with code written in other languages. Declarations that cause data to be allocated according to the C++ object model, that is, declarations for other than POD (Plain Old Data) objects, cannot generally be shared reliably with other languages, and should only appear in regions of source that are subject to the default `extern_model` of `relaxed_refdef`.

Within regions of source subject to an `extern_model` other than `relaxed_refdef`, declarations that allocate data with names visible to the linker should be limited exclusively to POD types. In particular, declaring a C++ class containing a static data member within such a region may produce unintended behavior.

---

After you select a global symbol model with `#pragma extern_model`, the compiler treats all subsequent declarations of objects of the `extern` storage class accordingly, until it encounters another `#pragma extern_model` directive.

The global symbol models are as follows:

- Common block model

In this model, all declarations are definitions and the linker combines all definitions with the same name into one definition. For Fortran program units, such `extern` variables appear as named `COMMON` blocks. The syntax is as follows:

```
#pragma extern_model common_block [(no)shr]
```

The `shr` and `nosh`r keywords determine whether the psects created for definitions are marked as shared or not shared. Fortran COMMON blocks normally have the shared attribute. If neither keyword is specified, the pragma acts as if `nosh`r was specified.

---

## Note

The C language permits objects declared with the `const` type qualifier to be allocated in read-only memory, and when the C compiler allocates a psect for a `const` object, it marks that section as read-only.

This is not compatible with the C++ conventions because the C++ language permits objects with static storage duration to be initialized with values computed at run-time (before the main function gains control). When the C++ compiler allocates a psect for such a declaration, it marks the psect writable. Normally, only one compilation (the one responsible for initialization) will allocate a psect for a `const` object, and there is no problem.

But under the `common_block` extern model, the compilers will always allocate a psect for such a declaration, leading to a "conflicting attributes" warning from the linker if the same `const`-qualified declaration is processed by both C and C++. It is best to avoid use of the `common_block` extern model when `const` objects with external linkage are shared between C and C++. If the `common_block` model must be used, then the `const` type qualifier should be removed (for example, by preprocessor conditionals) from the declaration processed by the C compiler.

---

- Relaxed refdef model

This model is the default. Some declarations are references and some are definitions. Multiple uninitialized definitions for the same object are allowed and resolved into one by the linker. However, a reference requires that at least one definition exists. The syntax is as follows:

```
#pragma extern_model relaxed_refdef [(no)shr]
```

The `shr` and `nosh`r keywords determine whether the psects created for definitions are marked as shared or not shared. If neither keyword is specified, the pragma acts as if `nosh`r was specified.

- Strict refdef model

In this model, some declarations are references and some are definitions. It requires exactly one definition in the program for each symbol referenced. The syntax is as follows:

```
#pragma extern_model strict_refdef ["name"] [(no)shr]
```

If specified, *name* in quotes is the name of the psect for any definition.

`shr` and `nosh`r keywords determine whether the psects created for definitions are marked as shared or not shared. Neither keyword can be specified unless a name for the psect is given. If neither keyword is specified, the pragma acts as if `nosh`r was specified.

- Globalvalue model

This model is like the strict refdef model except that these global objects have no storage; instead, global objects are link-time constant values. The syntax is as follows:

```
#pragma extern_model globalvalue
```

- Save

This pragma pushes the current `extern` model of the compiler onto a stack. The stack records all the information associated with the `extern` model. The syntax is as follows:

```
#pragma extern_model save
```

- Restore

This pragma pops the `extern` model stack of the compiler. The compiler's `extern` model is set as the state just popped off the stack. The stack records all the information associated with the `extern` model. The syntax is as follows:

```
#pragma extern_model restore
```

---

## Note

- The global symbols and psect names generated under the control of this pragma obey the case-folding rules of the `/NAME` qualifier. Supported for OpenVMS Alpha and IA-64 systems.
- While `#pragma extern_model` can be used to allocate several variables in the same psect, the placement of variables relative to each other within that psect cannot be controlled: the compiler does not necessarily allocate distinct variables to memory locations according to the order of appearance in the source code.

Furthermore, the order of allocation can change as a result of seemingly unrelated changes to the source code, command-line options, or from one version of the compiler to the next; it is essentially unpredictable. The only way to control the placement of variables relative to each other is to make them members of the same `struct` type or, on OpenVMS Alpha systems, by using the `noreorder` attribute on a named `#pragma extern_model strict_refdef`.

---

The `#pragma extern_model` directive has the following syntax:

```
#pragma extern_model model_spec [attr[,attr]...]
```

*model\_spec* is one of the following:

```
common_block  
relaxed_refdef  
strict_refdef "name"  
strict_refdef (No attr specifications allowed)  
globalvalue (No attr specifications allowed)
```

[*attr*[,*attr*]...] are optional psect attribute specifications chosen from the following (at most one from each line):

```
gbl lcl (Not allowed with relaxed_refdef)  
shr noshr  
wrt nowrt  
pic nopic (IA-64 only)  
ovr con  
rel abs (Alpha and IA-64)  
exe noexe  
vec novec
```

For OpenVMS Alpha and IA-64 systems: 0 byte 1 word 2 long 3 quad 4 octa 5 6 7  
8 9 10 11 12 13 14 15 16 page

The last line of attributes are numeric alignment values. When a numeric alignment value is specified on a section, the section is given an alignment of two raised to that power. Supported for OpenVMS Alpha and IA-64 systems.

On OpenVMS Alpha and IA-64 systems, the `strict_refdef "name" extern_model` can also take the following psect attribute specifications:

- `noreorder` — causes variables in the section to be allocated in the order they are defined.
- `natalgn` — has no effect on OpenVMS systems.

Table 2.1, "Program-Section Attributes" lists the attributes that can be applied to program sections.

**Table 2.1. Program-Section Attributes**

Attribute	Meaning
PIC or NOPIC	The program section or the data these attributes refers to does not depend on any specific virtual memory location (PIC), or else the program section depends on one or more virtual memory locations (NOPIC).
CON or OVR	The program section is concatenated with other program sections with the same name (CON) or overlaid on the same memory locations (OVR).
REL or ABS	The data in the program section can be relocated within virtual memory (REL) or is not considered in the allocation of virtual memory (ABS).
GBL or LCL	The program section is part of one cluster, is referenced by the same program section name in different clusters (GBL), or is local to each cluster in which its name appears (LCL).
EXE or NOEXE	The program section contains executable code (EXE) or does not contain executable code (NOEXE).
WRT or NOWRT	The program section contains data that can be modified (WRT) or data that cannot be modified (NOWRT).
RD or NORD	These attributes are reserved for future use.
SHR or NOSHR	The program section can be shared in memory (SHR) or cannot be shared in memory (NOSHR).
USR or LIB	These attributes are reserved for future use.
VEC or NOVEC	The program section contains privileged change mode vectors (VEC) or does not contain those vectors (NOVEC).
COM or NOCOM	The program section is a conditionally defined psect associated with a conditionally defined symbol. This is the type of psect created when you declare an uninitialized definition with <code>extern_model relaxed_refdef</code> .

See the *VSI OpenVMS Linker Utility Manual* for more complete information on each.

The default attributes are: `noshr, rel, noexe, novect, nopic`.

For `strict_refdef`, the default is `con`. For `common_block` and `relaxed_refdef`, the default is `ovr`.

The default for `wrt/nowrt` is determined by the first variable placed in the psect. If the variable has the `const` type qualifier (or the `readonly` modifier), the psect is set to `nowrt`. Otherwise, it is set to `wrt`.

On OpenVMS x86-64, by default all sections have the `wrt` attribute specified.

## Restrictions on Setting Psect Attributes

Be aware of the following restriction on setting psect attributes.

The `#pragma extern_model` directive does not set psect attributes for variables declared as tentative definitions in the `relaxed_refdef` model. A tentative definition is one that does not contain an initializer. For example, consider the following code:

```
#pragma extern_model relaxed_refdef long
int a;
int b = 6;
#pragma extern_model common_block long
int c;
```

Psect A is given octaword alignment (the default) because `a` is a tentative definition. Psect B is correctly given longword alignment because it is initialized and is, therefore, not a tentative definition. Psect C is also given longword alignment because it is declared in an `extern_model` other than `relaxed_refdef`.

---

### Note

The psect attributes are normally used by system programmers who need to perform declarations normally done in macro. Most of these attributes are not needed in normal C programs. Also, notice that the setting of attributes is supported only through the `#pragma` mechanism, and not through the `/EXTERN_MODEL` command-line qualifier.

---

### 2.1.1.5. #pragma extern\_prefix Directive

The `#pragma extern_prefix` directive controls the compiler's synthesis of external names, which the linker uses to resolve external name requests. When you specify `#pragma extern_prefix` with a string argument, the compiler prepends the string to all external names produced by the declarations that follow the pragma specification.

This pragma is useful for creating libraries where the facility code can be attached to the external names in the library.

The syntax is as follows:

```
                                "string"
#pragma extern_prefix save
                                restore
```

#### **"string"**

Prepends the quoted string to external names in the declarations that follow the pragma specification.

#### **save**

Saves the current pragma prefix string.

#### **restore**

Restores the saved pragma prefix string.

The default external prefix, when none has been specified by a pragma, is the null string. The recommended use is as follows:

```
#pragma extern_prefix save
#pragma extern_prefix "prefix-to-prepend-to-external-names"
... some declarations and definitions ...
#pragma extern_prefix restore
```

When an `extern_prefix` is in effect and you are using `#include` to include header files, but do not want the `extern_prefix` to apply to extern declarations in the header files, use the following code sequence:

```
#pragma extern_prefix save
#pragma extern_prefix ""
#include ...
#pragma extern_prefix restore
```

Otherwise, the external identifiers for definitions in the included files will be prepended with the external prefix.

All external names prefixed with a nonnull string using `#pragma extern_prefix` are converted to uppercase letters regardless of the setting of the `/NAMES` qualifier.

The compiler treats `#pragma extern_prefix` independently of the `/PREFIX_LIBRARY_ENTRIES` qualifier. The `/PREFIX_LIBRARY_ENTRIES` qualifier affects only ANSI and C Run-Time Library (RTL) entries; the `extern_prefix` pragma affects external identifiers for any externally visible name.

### 2.1.1.6. #pragma function Directive (Alpha and IA-64 only)

The `#pragma function` directive specifies that calls to the specified functions will occur in the source code. You normally use this directive in conjunction with `#pragma intrinsic`, which affects specified functions that follow the pragma directive. The effect of `#pragma intrinsic` on a given function continues to the end of the source file or until a `#pragma function` directive occurs, specifying that function.

The `#pragma function` directive has the following syntax:

```
#pragma function (function1[,function2, ...])
#pragma function ()
```

You cannot specify this pragma with empty parentheses. To disable all intrinsic functions, specify the `/OPTIMIZE=NOINTRINSICS` qualifier on the command line.

### 2.1.1.7. #pragma include\_directory Directive

The effect of each `#pragma include_directory` is as if its string argument (including the quotes) were appended to the list of places to search that is given its initial value by the `/INCLUDE_DIRECTORY` qualifier, except that an empty string is not permitted in the pragma form.

The `#pragma include_directory` directive has the following syntax:

```
#pragma include_directory <string-literal>
```



This pragma is intended to ease DCL command-line length limitations when porting applications from POSIX-like environments built with makefiles containing long lists of -I options that specify directories to search for headers. Just as long lists of macro definitions specified by the /DEFINE qualifier can be converted to #define directives in a source file, long lists of places to search specified by the /INCLUDE\_DIRECTORY qualifier can be converted to #pragma include\_directory directives in a source file.

Note that the places to search, as described in the help text for the /INCLUDE\_DIRECTORY qualifier, include the use of POSIX-style pathnames, for example "/usr/base". This form can be very useful when compiling code that contains POSIX-style relative pathnames in #include directives. For example, #include <subdir/foo.h> can be combined with a place to search such as "/usr/base" to form "/usr/base/subdir/foo.h", which will be translated to the filespec "USR:[BASE.SUBDIR]FOO.H"

This pragma can appear only in the main source file or in the first file specified on the /FIRST\_INCLUDE qualifier. Also, it must appear before any #include directives.

### 2.1.1.8. #pragma [no]inline Directive (Alpha and IA-64 only)

The #pragma inline directive expands function calls inline. The function call is replaced with the function code itself.

The #pragma inline directive has the following syntax:

```
#pragma inline (id,...)
#pragma noline (id,...)
```

If a function is named in an inline directive, calls to that function will be expanded as inline code, if possible.

If a function is named in a noline directive, calls to that function will not be expanded as inline code.

If a function is named in both an inline and a noline directive, an error message is issued.

For calls to functions named in neither an inline nor a noline directive, C++ expands the function as inline code whenever appropriate as determined by a platform-specific algorithm.

### 2.1.1.9. #pragma intrinsic Directive (Alpha and IA-64 only)

The #pragma intrinsic directive specifies that calls to the specified functions are intrinsic. Intrinsic functions are functions in which the compiler generates optimize code in certain situations, possibly avoiding a function call.

The #pragma intrinsic directive has the following syntax:

```
#pragma intrinsic (function1[,function2, ...])
```

You can use this directive to make intrinsic the default form of functions that have intrinsic forms. The following functions have intrinsic forms:

```
abs
fabs
labs
alloca
```

You can use the #pragma function directive to override the #pragma intrinsic directive for specified functions.

The function must have a declaration visible at the time the compiler encounters the `#pragma intrinsic` directive. The compiler takes no action if the compiler does not recognize the specified function name as an intrinsic.

### 2.1.1.10. `#pragma [no]member_alignment` Directive

By default, the compiler for OpenVMS systems aligns structure members so that members are stored on the next boundary appropriate to the type of the member; that is, bytes are on the next byte boundary, words are on the next word boundary, and so on.

You can use the `#pragma member_alignment` directive to specify structure member alignment explicitly.

Using `#pragma nomember_alignment` causes the compiler to align structure members on the next byte boundary regardless of the type of the member. The only exception to this is for bit-field members.

This pragma has the following formats:

```
#pragma member_alignment
#pragma member_alignment save
#pragma member_alignment restore
#pragma nomember_alignment [base_alignment]
```

When `#pragma member_alignment` is used, the compiler aligns structure members on the next boundary appropriate to the type of the member, rather than on the next byte. For example, a `long` variable is aligned on the next longword boundary; a `short` variable is aligned on the next word boundary.

Consider the following example:

```
#pragma nomember_alignment

struct x {
    char c;
    int b;
};

#pragma member_alignment

struct y {
    char c;          /*3 bytes of filler follow c */
    int b;
};

main ()
{
    printf( "The sizeof y is: %d\n", sizeof (struct y) );
    printf( "The sizeof x is: %d\n", sizeof (struct x) );
}
```

When this example is executed, it shows the difference between `#pragma member_alignment` and `#pragma nomember_alignment`.

Once used, the `member_alignment` pragma remains in effect until the `nomember_alignment` pragma is encountered; the reverse is also true.

The optional *base\_alignment* parameter can be used to specify the base-alignment of the structure. Use one of the following keywords for the *base\_alignment*:

- `byte` (1 byte)
- `word` (2 bytes)
- `longword` (4 bytes)
- `quadword` (8 bytes)
- `octaword` (16 bytes)

The `#pragma member_alignment save` and `#pragma member_alignment restore` directives can be used to save the current state of the `member_alignment` and to restore the previous state, respectively. This feature is necessary for writing header files that require `member_alignment` or `nomember_alignment`, or that require inclusion in a `member_alignment` that is already set.

To affect the member alignment of the entire module, use the `/MEMBER_ALIGNMENT` qualifier. For information about this qualifier, see *Section 2.2.14.1, "Structure Alignment"*.

The x86-64 compiler has some subtle differences compared to Alpha and IA-64:

1. In IA-64 CXX:

```
struct
/*
** This directive does not change the alignment of s1 because we've
** already started the struct.
*/
#pragma nomember_alignment
{
...
} s1;
```

OpenVMS x86-64, it does change the alignment. It is best to use the pragma prior to the struct definition.

2. In IA-64 CXX the `#pragma pack` cancels the base alignment defined by

```
#pragma nomember_alignment <base_alignment>
```

OpenVMS x86-64, the `#pragma pack` has no effect on base alignment.

### 2.1.1.11. #pragma message Directive

The **#pragma message** directive controls the kinds of individual diagnostic messages or groups of messages that the compiler issues. Use this pragma to override any command-line options specified by the `/WARNINGS` qualifier, which affects the types of messages the compiler issues.

Default severities used by the compiler can be changed only if they are informationals, warnings, or discretionary errors. Attempts to change more severe severities are ignored. If a message severity has not been altered by the command line and is not currently being controlled by a pragma, the compiler checks to see whether the message severity should be changed because of the “quiet” state. If not, the message is issued using the default severity.

Error message severities start out with command-line severities applied to default compiler severities. Pragma message severities are then applied. In general, pragma severities override command-line

severities, which override default severities. The single exception to this is that command-line options can always be used to downgrade messages. However, command-line qualifiers cannot be used to raise the severity of messages currently controlled by pragmas.

The `#pragma message` directive has the following syntax:

```
#pragma message disable (message-list)
#pragma message enable (message-list)
#pragma message error (message-list)
#pragma message fatal (message-list)
#pragma message informational (message-list)
#pragma message warning (message-list)
#pragma message restore
#pragma message save
```

### **disable**

Suppresses the compiler-issued messages specified in the *message-list* argument. The *message-list* argument can be any one of the following:

- A single message identifier
- The keyword ALL (all messages issued by the compiler)
- A single message identifier enclosed in parentheses
- A comma-separated list of message identifiers enclosed in parentheses

A message identifier is the name immediately following the message severity code letter. For example, consider the following message:

```
%CXX-W-MISSINGRETURN, Non-void function "name" does not contain a return
statement
```

The message identifier is `MISSINGRETURN`. To prevent the compiler from issuing this message, use the following directive:

```
#pragma message disable MISSINGRETURN
```

The compiler lets you disable a discretionary message if its severity is warning (W), informational (I), or error (E) at the time the message is issued. If the message has severity of fatal (F), the compiler issues it regardless of instructions not to issue messages.

### **enable**

Enables the compiler to issue the messages specified in the *message-list* argument.

### **errors**

Sets the severity of each message in the message list to Error.

### **fatals**

Sets the severity of each message in the message list to Fatal.

### **informationals**

Sets the severity of each message in the message list to Informational.

### **warnings**

Sets the severity of each message in the message list to Warning.

**restore**

Restores the saved state of enabling or disabling compiler messages.

**save**

Saves the current state of enabling or disabling compiler messages.

The `save` and `restore` options are useful primarily within header files. See *Section 2.1.1.5*, *"#pragma extern\_prefix Directive"*.

`#pragma message` performs macro expansion so that you map Version 5.6 message tags to Version 6.0 tags:

```
...
#if __DECCXX_VER > 60000000
#define unittest used_before_set
#endif

#pragma message disable unittest
int main()
{
    int i,j;

    i=j;
}
#pragma message enable unittest
```

On OpenVMS x86-64 the **#pragma message** directive has the following format:

```
#pragma message [option] ("message-list")
```

The message-list must be enclosed in double quotes and parentheses, with the values separated by spaces.

The IA-64 CXX compiler does not support message identifiers (they are silently ignored); you should use clang's respective message IDs.

Once a message severity is set to error or fatal, it cannot be downgraded to a warning. However, it is possible to reduce the severity from fatal to error.

### 2.1.1.12. #pragma module Directive (Alpha and IA-64 only)

When you compile source files to create an object file, the compiler assigns the first of the file names specified in the compilation unit to the name of the object file. The compiler adds the `.OBJ` file extension to the object file. Internally, the OpenVMS system (the debugger and the librarian) recognizes the object module by the file name; the compiler also gives the module a version number of 1. For example, given the object file `EXAMPLE.OBJ`, the debugger recognizes the `EXAMPLE` object module.

To change the system-recognized module name and version number, use the `#pragma module` directive.

You can find the module name and the module version number listed in the compiler listing file and the linker load map.

The `#pragma module` directive is equivalent to the VAX C compatible `#module` directive.

The `#pragma module` directive has the following syntax:

```
#pragma module identifier identifier
```

```
#pragma module identifier string
```

The first parameter must be a valid identifier, which specifies the name of the module to be used by the linker. The second parameter specifies the optional identification that appears on the listing and in the object file. The second parameter must be a valid identifier of no more than 31 characters, or a character-string constant of no more than 31 characters.

### **2.1.1.13. #pragma once Directive**

The `#pragma once` preprocessor directive specifies that the header file is evaluated only once.

The `#pragma once` directive has the following format:

```
#pragma once
```

### **2.1.1.14. #pragma pack Directive**

The `#pragma pack` directive specifies the byte boundary for packing member's structures.

The `#pragma pack` directive has the following format:

```
#pragma pack [(n)]
#pragma pack(push {, identifier} {, n})
#pragma pack(pop {, identifier} {, n})
```

*n* specifies the new alignment restriction in bytes as follows:

1	Align to byte
2	Align to word
4	Align to longword
8	Align to quadword
16	Align to octaword

A structure member is aligned to either the alignment specified by `#pragma pack` or the alignment determined by the size of the structure member, whichever is smaller. For example, a short variable in a structure gets byte-aligned if `#pragma pack (1)` is specified. If `#pragma pack (2) (4)`, or `(8)` is specified, the short variable in the structure gets aligned to word.

If `#pragma pack` is not used, or if *n* is omitted, packing defaults to 1 for byte alignment.

With the push/pop syntax of this pragma, you can save and restore packing alignment values across program components. This allows you to combine components into a single translation unit even if they specify different packing alignments:

- Every occurrence of `pragma pack` with a push argument stores the current packing alignment value on an internal compiler stack. If you provide a value for *n*, that value becomes the new packing value. If you specify an *identifier*, a name of your choosing, it is associated with the new packing value.
- Every occurrence of a `pragma pack` with a pop argument retrieves the value at the top of the stack and makes that value the new packing alignment. If an empty stack is popped, the alignment value defaults to the `/[NO]MEMBER_ALIGNMENT` command-line setting, and a warning is issued. If you specify a value for *n*, that value becomes the new packing value.

If you specify an *identifier*, all values stored on the stack are removed from the stack until a matching *identifier* is found. The packing value associated with the *identifier* is also removed from the stack, and the packing value that was in effect just before the *identifier* was pushed becomes the new packing value. If no matching *identifier* is found, the packing value reverts to the command-line setting, and a warning is issued.

On OpenVMS x86-64, if you use a **pop** with an *identifier* that is not found in any record on the stack, the **pop** is ignored.

The push/pop syntax of `pragma pack` lets you write header files that ensure that packing values are the same before and after the header file is encountered. Consider the following example:

```
// File name: myinclude.h
//
#pragma pack( push, enter_myinclude )
// Your include-file code ...
#pragma pack( pop, enter_myinclude )
// End of myinclude.h
```

In this example, the current packing value is associated with the identifier `enter_myinclude` and pushed on entry to the header file. Your include code is processed. The `#pragma pack` at the end of

the header file then removes all intervening packing values that might have occurred in the header file, as well as the packing value associated with `enter_myinclude`, thereby preserving the same packing value after the header file as before it.

This syntax also lets you include header files that might set packing alignments different from the ones set in your code. Consider the following example:

```
#pragma pack( push, before_myinclude )
#include <myinclude.h>
#pragma pack( pop, before_myinclude )
```

In this example, your code is protected from any changes to the packing value that might occur in `<myinclude.h>` by saving the current packing alignment value, processing the include file (which may leave the packing alignment with an unknown setting), and restoring the original packing value.

### 2.1.1.15. #pragma unroll Directive (Alpha only)

The `#pragma unroll` preprocessor directive unrolls the `for` loop that follows it by the number of times specified in `unroll_factor`. The `#pragma unroll` directive must be followed by a `for` statement.

This directive has the following format:

```
#pragma unroll unroll_factor
```

The `unroll_factor` is an integer constant in the range of 0 to 255. If a value of 0 is specified, the compiler ignores the directive and determines the number of times to unroll the loop in its normal way. A value of 1 prevents the loop from being unrolled. The directive applies only to the `for` loop that follows it, not to any subsequent `for` loops.

### 2.1.1.16. #pragma [no]standard Directive (Alpha and IA-64 only)

This directive performs operations similar to the save and restore options on `#pragma message` directive:

- `#pragma standard` is the same as `#pragma message restore`.
- `#pragma nostandard` disables all optional messages after doing a `#pragma message save` operation.

## 2.1.2. Predefined Macros and Names

The compiler defines the following predefined macros and predefined names. For information on using predefined macros in header files in the common language environment, see *Section 3.2, "Using Existing C Header Files"*.

**Table 2.2. Predefined Macros on OpenVMS Alpha and IA-64**

Macro	Description
<code>_BOOL_EXISTS</code>	Indicates that <code>bool</code> is a type or keyword
<code>__BOOL_IS_A_RESERVED_WORD</code>	Indicates that <code>bool</code> is a keyword
<code>__DATE__</code> <sup>1</sup>	A string literal containing the date of the translation in the form <code>Mmm dd yyyy</code> , or <code>Mmm d yyyy</code> if the value of the date is less than 10



Macro	Description
<code>__FILE__</code> <sup>1</sup>	A string literal containing the name of the source file being compiled
<code>__IEEE_FLOAT</code>	Identifies floating-point format for compiling the program. The default value is 1 for OpenVMS IA-64 systems, and 0 for OpenVMS Alpha and VAX systems.
<code>__LINE__</code> <sup>1</sup>	A decimal constant containing the current line number in the C++ source file
<code>__PRAGMA_ENVIRONMENT</code>	Indicates that the <code>pragma environment</code> directive is supported.
<code>__TIME__</code> <sup>1</sup>	A string literal containing the time of the translation in the form of <code>hh:mm:ss</code>
<code>_WCHAR_T</code>	Indicates that <code>wchar_t</code> is a keyword

<sup>1</sup>Cannot be redefined or undefined

**Table 2.3. Predefined Macros on OpenVMS x86-64**

Macro	Description
<code>__DATE__</code> <sup>1</sup>	A string literal containing the date of the translation in the form <code>Mmm dd yyyy</code> , or <code>Mmm d yyyy</code> if the value of the date is less than 10
<code>__FILE__</code> <sup>1</sup>	A string literal containing the name of the source file being compiled
<code>__IEEE_FLOAT</code>	Identifies floating-point format for compiling the program. The default value is 1.
<code>__LINE__</code> <sup>1</sup>	A decimal constant containing the current line number in the C++ source file
<code>__TIME__</code> <sup>1</sup>	A string literal containing the time of the translation in the form of <code>hh:mm:ss</code>
<code>__llvm__</code>	A predefined macro indicating the use of the LLVM compiler infrastructure.
<code>__clang__</code>	A predefined macro indicating the use of the Clang compiler.
<code>__clang_major__</code>	An integer constant representing the major version number of the Clang compiler.
<code>__clang_minor__</code>	An integer constant representing the minor version number of the Clang compiler.
<code>__clang_patchlevel__</code>	An integer constant representing the patch level of the Clang compiler.
<code>__clang_version__</code>	A string literal containing the complete version of the Clang compiler.
<code>__amd64__</code>	A predefined macro used to identify the AMD64 architecture.
<code>__amd64</code>	A predefined macro used to identify the AMD64 architecture.
<code>__x86_64</code>	A predefined macro used to identify the x86-64 architecture.

Macro	Description
<code>__x86_64__</code>	A predefined macro used to identify the x86-64 architecture.
<code>__VMS</code>	A predefined macro used to identify the OpenVMS operating system.
<code>__vms</code>	A predefined macro used to identify the OpenVMS operating system.
<code>__vms_host__</code>	A predefined macro used to identify the host environment as OpenVMS.
<code>__CRTL_VER</code>	An integer constant representing the encoded version of the C Run-Time Library.
<code>CRTL_VER</code>	An integer constant representing the encoded version of the C Run-Time Library.
<code>__STDC_VERSION__</code>	A long integer constant indicating the version of the C standard being used, encoded as a date.
<code>__IEEE_FLOAT</code>	A predefined macro indicating that IEEE floating-point arithmetic is used.
<code>_IEEE_FP</code>	A predefined macro indicating that IEEE floating-point arithmetic is used.
<code>__G_FLOAT</code>	A predefined macro indicating that VAX G floating-point arithmetic is not used.
<code>__D_FLOAT</code>	A predefined macro indicating that VAX D floating-point arithmetic is not used.
<code>__USING_STD_STAT</code>	A predefined macro indicating the use of a standard-compliant state structure.
<code>_USE_STD_STAT</code>	A predefined macro indicating the use of a standard-compliant state structure.
<code>_LIBCPP_LITTLE_ENDIAN</code>	A predefined macro indicating that the system uses little-endian byte order.
<code>__INITIAL_POINTER_SIZE</code>	An integer constant indicating the initial size of pointers used by the program.
<code>__ELF__</code>	A predefined macro indicating support for the ELF (Executable and Linkable Format) binary format.
<code>_REENTRANT</code>	A predefined macro indicating that the C Run-Time Library supports reentrant functions.
<code>__CAN_USE_EXTERN_PREFIX</code>	A predefined macro indicating support for the <b>#pragma extern_prefix</b> directive.
<code>_GNU_SOURCE</code>	A predefined macro indicating that GNU extensions are enabled.
<code>__FLOAT128__</code>	A predefined macro indicating that 128-bit floating point arithmetic is supported.
<code>__vms_version</code>	A string literal containing the version of the OpenVMS operating system.
<code>__VMS_VERSION</code>	A string literal containing the version of the OpenVMS operating system.

Macro	Description
<code>__vms_ver</code>	An integer constant representing the encoded version of the OpenVMS operating system.
<code>__VMS_VER</code>	An integer constant representing the encoded version of the OpenVMS operating system.
<code>__VSICXX_VER</code>	An integer constant representing the encoded version of the C++ compiler.
<code>__RTTI</code>	A predefined macro indicating that Run-Time Type Information (RTTI) is supported.
<code>__EXCEPTIONS</code>	A predefined macro indicating that exception handling is supported.

<sup>1</sup>Cannot be redefined or undefined

Table 2.4, "Names with a Defined Value of 1" lists names with a defined value of 1.

**Table 2.4. Names with a Defined Value of 1**

Name	Description
<code>__cplusplus</code> <sup>1</sup>	Language identification name
<code>__DECCXX</code>	Language identification name
<code>__VMS</code>	System identification
<code>__vms</code>	System identification

<sup>1</sup>Cannot be redefined or undefined

The compiler predefines `__VMS`; the C compiler predefines `VMS` and `__VMS`. Therefore, C++ programmers who plan to reuse code should check for `__VMS`.

On OpenVMS systems, the compiler supports the following predefined macro names.

**Table 2.5. Predefined Macros Specific to OpenVMS Systems**

Name	Description
<code>__Alpha_AXP</code>	System identification name
<code>__ALPHA</code>	System identification name
<code>__alpha</code>	System identification name
<code>__32BITS</code>	Defined when pointers and data of type <code>long</code> are 32 bits on Alpha platforms

The compiler predefines `__32BITS` when pointers and data of type `long` are 32 bits on Alpha platforms.

On OpenVMS operating systems, programmers should use the predefined macro `__alpha` for code that is intended to be portable from one system to the other.

On OpenVMS I64 systems, the compiler supports the following predefined macro names:

**Table 2.6. Predefined Macros Specific to OpenVMS I64 Systems**

Name	Description
<code>__ia64</code>	System identification name

Name	Description
<code>__ia64__</code>	System identification name
<code>__32BITS</code>	Defined when pointers and data of type <code>long</code> are 32 bits.

Predefined macros (with the exception of `vms_version`, `VMS_VERSION`, `__vms_version`, `__VMS_VERSION`, and `__INITIAL_POINTER_SIZE`) are defined as 1 or 0, depending on the system (VAX or Alpha processor), the compiler defaults, and the qualifiers used. For example, if you compiled using `G_FLOAT` format, `__D_FLOAT` and `__IEEE_FLOAT` (Alpha processors only) are predefined to be 0, and `__G_FLOAT` is predefined as if the following were included before every compilation unit:

```
#define __G_FLOAT 1
```

These macros can assist in writing code that executes conditionally. They can be used in `#elif`, `#if`, `#ifdef`, and `#ifndef` directives to separate portable and nonportable code in a C++ program. The `vms_version`, `VMS_VERSION`, `__vms_version`, and `__VMS_VERSION` macros are defined with the value of the OpenVMS version on which you are running (for example, Version 6.0).

C++ automatically defines the following macros pertaining to the format of floating-point variables. You can use them to identify the format with which you are compiling your program.

```
__D_FLOAT
__G_FLOAT
__IEEE_FLOAT
__IEEE_FP
__X_FLOAT
```

The value of `__X_FLOAT` can be 0 or 1 depending on the floating point mode in effect. You can use the `/FLOAT` qualifier to change the mode.

Table 2.7, "Version String and Version Number Macros" lists predefined version string and version number macros.

**Table 2.7. Version String and Version Number Macros**

Name	Description
<code>__VMS_VERSION</code> <sup>1</sup>	Version identification
<code>__vms_version</code> <sup>1</sup>	Version identification
<code>__DECCXX_VER</code> <sup>2</sup>	Version identification
<code>__VMS_VER</code> <sup>2</sup>	Version identification

<sup>1</sup>The value is a character string.

<sup>2</sup>The value is an unsigned long int that encodes the version number.

For example, the defined value of `__VMS_VERSION` on OpenVMS Version 6.1 is character string `V6.1`.

You can use `__DECCXX_VER` to test that the current compiler version is newer than a particular version and `__VMS_VER` to test that the current OpenVMS Version is newer than a particular version. Newer versions of the compiler and the OpenVMS operating system always have larger values for these macros. If for any reason the version cannot be analyzed by the compiler, then the corresponding predefined macro is defined but has the value of 0. Releases of the compiler prior to Version 5.0 do not

define these macros, so you can distinguish earlier compiler versions by checking to determine if the `__DECCXX_VER` macro is defined.

The following example tests for C++ 5.1 or higher:

```
#ifdef __DECCXX_VER
    #if __DECCXX_VER >= 50100000
        /* Code */
    #endif
#endif
```

The following tests for OpenVMS Version 6.2 or higher:

```
#ifdef __VMS_VER
    #if __VMS_VER >= 60200000
        /* code */
    #endif
#endif
```

Table 2.8, "Macros Defined by Command-Line Qualifiers on OpenVMS Alpha and IA-64 Systems" shows the macro names for the listed command-line options.

**Table 2.8. Macros Defined by Command-Line Qualifiers on OpenVMS Alpha and IA-64 Systems**

Command-line Option	Macro Name
/ALTERNATIVE_TOKENS	__ALTERNATIVE_TOKENS
/ASSUME=GLOBAL_ARRAY_NEW	__GLOBAL_ARRAY_NEW
/ASSUME=STDNEW	__STDNEW
/DEFINE=__FORCE_INSTANTIATIONS (Alpha only)	__FORCE_INSTANTIATIONS
/EXCEPTIONS	__EXCEPTIONS
/IEEE_MODE	__IEEE_FP
/IMPLICIT_INCLUDE	__IMPLICIT_INCLUDE_ENABLED
/L_DOUBLE_SIZE	__X_FLOAT
/MODEL=ANSI	__MODEL_ANSI
/MODEL=ARM (Alpha only)	__MODEL_ARM
/PURE_CNAME	__PURE_CNAME, __HIDE_FORBIDDEN_NAMES <sup>1</sup>
/ROUNDING_MODE	__BIASED_FLT_ROUNDS
/RTTI	__RTTI
/STANDARD=RELAXED	__STD_ANSI, __NOUSE_STD_Iostream
/STANDARD=ANSI	__STD_ANSI, __NOUSE_STD_Iostream
/STANDARD=ARM	__STD_ARM, __NOUSE_STD_Iostream
/STANDARD=CFRONT	The CFRONT option is no longer supported.
/STANDARD=GNU	__STD_GNU, __NOUSE_STD_Iostream
/STANDARD=MS	__STD_MS, __NOUSE_STD_Iostream
/STANDARD=STRICT_ANSI	__STD_STRICT_ANSI, __USE_STD_Iostream,

Command-line Option	Macro Name
	__PURE_CNAME, __HIDE_FORBIDDEN_NAMES (Alpha and IA-64 only)
/STANDARD=STRICT_ANSI /WARNINGS=ANSI_ERRORS	__STD_STRICT_ANSI_ERRORS, __PURE_CNAME, __HIDE_FORBIDDEN_NAMES
/USING=STD	__IMPLICIT_USING_STD
/STANDARD=LATEST	__STD_STRICT_ANSI, __USE_STD_Iostream, __PURE_CNAME, __HIDE_FORBIDDEN_NAMES (Alpha and IA-64 only)
/STANDARD=LATEST /WARNINGS=ANSI_ERRORS	__STD_STRICT_ANSI_ERRORS, __PURE_CNAME, __HIDE_FORBIDDEN_NAMES

<sup>1</sup>When you compile with VSI C++ using any values of /STANDARD that set strict C++ standard conformance (ARM, MS, STRICT\_ANSI, and LATEST), versions of the standard header files are included that hide many identifiers that do not follow the rules. The header file <stdio.h>, for example, hides the definition of the macro TRUE. The compiler accomplishes this by predefining the macro \_\_HIDE\_FORBIDDEN\_NAMES for the above-mentioned /STANDARD values.

You can use the /UNDEFINE="\_\_HIDE\_FORBIDDEN\_NAMES" command-line qualifier to prevent the compiler from predefining this macro and, thereby, including macro definitions of the forbidden names.

## 2.1.3. Translation Limits

The only translation limits imposed in the compiler are as follows:

Limit	Meaning
32,767	Bytes in the representation of a string literal. This limit does not apply to string literals formed by concatenation.
8192	Characters in an internal identifier or macro name.
8192	Characters in a logical name.
8192	Characters in a physical source line, on OpenVMS systems.
1012	Bytes in any one function argument.
512	Characters in a physical source line, on OpenVMS Alpha systems.
255	Arguments in a function call. <sup>1</sup>
255	Parameters in a function definition. <sup>1</sup>
127	Characters in a qualified identifier in the debugger.
31	Significant characters in an external identifier with "C" linkage. A warning is issued if such an identifier is truncated.

<sup>1</sup>The compiler may add one or two hidden arguments to a function, which reduces to 254 or 253 the number of arguments available to the user.

## 2.1.4. Numerical Limits

The numerical limits, as defined in the header files <limits.h> and <float.h> are as follows:

- The number of bits in a character of the execution character set is eight.
- The representation and set of values for type `char` and for type `signed char` are the same. You can change this equivalence from `signed char` to `unsigned char` with a command-line option.
- The representation and set of values for the `short` type is 16 bits.

- The representation and set of values for type `double` are 64 bits.
- The representation and set of values for type `long double` are 128 bits unless the `/L_DOUBLE_SIZE=64`) qualifier is specified.

Specifying a different `l_double_size` than the default size for your particular version of the operating system does not work correctly with the standard library.

- The representation and set of values for the types `int`, `signed int`, and `unsigned int` are 32 bits
- On OpenVMS Alpha and OpenVMS IA-64, the representation and set of values for the types `long` and `unsigned long` are 32 bits
- On OpenVMS x86-64, the representation and set of value for the types `long` and `unsigned long` are 64-bits

## 2.1.5. Argument-Passing and Return Mechanisms

The compiler passes arrays, functions, and class objects with a constructor or destructor by reference. All other objects are passed by value.

If a class has a constructor or a destructor, it is not passed by value. In this case, the compiler calls a copy constructor to copy the object to a temporary location, and passes the address of that location to the called function.

On OpenVMS IA-64 and Alpha if the return value of a function is a class that has defined a constructor or destructor or is greater than 64 bits, storage is allocated by the caller and the address to this storage is passed in the first parameter to the called function. The called function uses the storage provided to construct the return value.

On OpenVMS x86-64 if the return value of a function is a class that has defined a constructor or destructor or is greater than 128 bits, storage is allocated by the caller and the address to this storage is passed in the first parameter to the called function.

## 2.2. Implementation Extensions and Features

This section describes the extensions and implementation-specific features of the compiler on OpenVMS systems.

### 2.2.1. Identifiers

In the compiler, the dollar sign (\$) is a valid character in an identifier.

For each external function with C++ linkage, the compiler decorates the function name with a representation of the function's type.

#### 2.2.1.1. External Name Encoding

On OpenVMS IA-64 and Alpha systems the compiler uses the external name encoding scheme described below.

For the basic types, the external name encoding scheme is as follows:

Type	Encoding
void	v
char	c
short	s
int	i
long	l
float	f
double	d
long double	r
...	e
bool	jb
wchar_t	jw

Class names are encoded as described per C++ rules, except that the VSI C++ compiler uses the lowercase `q` instead of uppercase `Q`, and denotes the qualifier count as a decimal number followed by an underscore, as follows:

Class	Notation	Encoding
simple	Complex	7Complex
qualified	X::YY	q2_1x2yy

Type modifiers are encoded as follows:

Modifier	Encoding
const	k
signed	g
volatile	w
unsigned	u
__unaligned	b

Type declarators are encoded as follows:

Type	Notation	Encoding
array	[ 10 ]	a10_
function	( )	x
pointer	*	p
pointer to member	S::*	m1S
reference	&	n
unnamed enumeration type		h

On OpenVMS systems, the compiler also supports the following data types:



Type	Encoding
<code>__int16</code>	<code>ji4</code>
<code>__int32</code>	<code>ji5</code>
<code>__int64</code>	<code>ji6</code>
<code>__f_float</code>	<code>jf</code>
<code>__g_float</code>	<code>yg</code>
<code>__s_float</code>	<code>js</code>
<code>__t_float</code>	<code>jt</code>

On OpenVMS x86-64, the external name encoding is based on Itanium C++ ABI. For more information refer to <https://itanium-cxx-abi.github.io/cxx-abi/abi.html#mangling>.

### 2.2.1.2. Modifying Long Names

On OpenVMS IA-64 and Alpha systems, if an identifier for a function name with C++ linkage exceeds 31 characters, the name is modified as follows:

1. A unique value is generated by hashing the full decorated name. This seven-character code is appended to the end of the name.
2. The name is preceded by the `cxx$` facility prefix.
3. The name is truncated in three back-to-front passes, eliminating underscores, then vowels, and then consonants (y is a consonant). A vowel is never removed if the following conditions apply:
  - It occurs as the first character in the fully decorated name.
  - The character before the vowel is either another vowel or is non-alphanumeric.

The hash code added at the end of the name is not truncated.

Truncation ceases when the truncated name, combined with the `cxx$` facility prefix and the unique radix 32 value at the end, equals 31 characters.

For information on how to view the demangled form of these names, see *Section 1.7, "Name Demangling"*.

On OpenVMS x86-64, the C++ compiler does not truncate names.

### 2.2.2. Order of Static Object Initialization

Nonlocal static objects are initialized in declaration order within a compilation unit and in link order across compilation units. On OpenVMS systems, the compiler uses the `lib$initialize` mechanism to initialize nonlocal static objects.

### 2.2.3. Integral Conversions

When demoting an integer to a signed integer, if the value is too large to be represented the result is truncated and the high-order bits are discarded.

Conversions between signed and unsigned integers of the same size involve no representation change.

## 2.2.4. Floating-Point Conversions

When converting an integer to a floating-point number that cannot exactly represent the original value, the compiler rounds off the result of the conversion to the nearest value that can be represented exactly.

When the result of converting a floating-point number to an integer or other floating-point number at compile time cannot be represented, the compiler issues a diagnostic message.

When converting an integral number or a double floating-point number to a floating-point number that cannot exactly represent the original value, rounds off the result to the nearest value of type `float`.

When demoting a `double` value to `float`, if the converted value is within range but cannot exactly represent the original value, the compiler rounds off the result to the nearest representable `float` value, the compiler performs similar rounding for demotions from `long double` to `double` or `float`.

## 2.2.5. The `sizeof` Operator

The type of the `sizeof` operator is `size_t`. In the header file, `stddef.h`, the compiler defines this type as `unsigned int`, which is the type of the integer that holds the maximum size of an array.

On OpenVMS x86-64 the CXX compiler `size_t` is defined as `unsigned long`, that is 64-bit.

## 2.2.6. Explicit Type Conversion

A pointer takes up the same amount of memory storage as objects of type `int` or `long` (or their unsigned equivalents). Therefore, a pointer can convert to any of these types and back again without changing its value. No scaling occurs and the representation of the value is unchanged.

Conversions to and from a shorter integer and a pointer are similar to conversions to and from a shorter integer and `unsigned long`. If the shorter integer type was signed, conversion fills the high-order bits of the pointer with copies of the sign bit.

On OpenVMS x86-64 the default size for pointers is 64-bits (same as the size of type `long`).

## 2.2.7. Multiplicative Operators

The semantics of the division (`/`) and remainder (`%`) operator are as follows:

- If either operand of the division operator is negative, the compiler truncates the result toward 0 (that is, the smallest integer larger than the algebraic quotient).
- If either operand of the remainder operator is negative, the result takes the same sign as that of the first operand.

In the following cases of undefined behavior detected at compile time, the compiler issues a warning:

Integer overflow  
Division by 0  
Remainder by 0

## 2.2.8. Additive Operators

You can subtract pointers to members of the same array. The result is the number of elements between the two array members, and is of type `ptrdiff_t`. In the header file `stddef.h`, the compiler defines this type as `int` on OpenVMS Alpha and OpenVMS IA-64 systems.

On OpenVMS x86-64 systems, `ptrdiff_t` is defined as `long` (64-bits).

## 2.2.9. Shift Operators

The expression `E1 >> E2` shifts `E1` to the right `E2` positions. If `E1` has a signed type, the compiler fills the vacated high-order bits of the shifted value `E1` with a copy of `E1`'s sign bit (arithmetic shift).

## 2.2.10. Equality Operators

When comparing two pointers to members, the compiler guarantees equality if either of the following conditions hold:

- Both pointers are `NULL`.
- The same address expression (`&`) created both pointers.

When comparing two pointers to members, the compiler guarantees inequality if either of the following conditions hold:

- Only one pointer is `NULL`.
- Each pointer produces a different member if applied to the same object.

When created by different address expressions, two pointers to members may compare either as equal or as unequal if they produce the same member when applied to the same object.

## 2.2.11. Type Specifiers

For variables that are modifiable in ways unknown to the compiler, use the `volatile` type specifier. Declaring an object to be volatile means that every reference to the object in the source code results in a reference to memory in the object code.

## 2.2.12. asm Declarations (Alpha only)

In the compiler, `asm` declarations produce a compile-time error. As an alternative to `asm`, you can use built-in functions. See *Appendix B, "Built-In Functions"* for more information.

## 2.2.13. Linkage Specifications

Specifying linkage other than `"C++"` or `"C"` generates a compile-time error.

In object files, the compiler decorates with type information the names of functions with C++ linkage. This permits overloading and provides rudimentary type checking across compilation units.

The type-encoding algorithm is based on Itanium C++ ABI. For more information refer to <https://itanium-cxx-abi.github.io/cxx-abi/abi.html#mangling>.

## 2.2.14. Class Layout

The alignment requirements and sizes of structure components affect the structure's alignment and size. A structure can begin on any byte boundary and occupy any integral number of bytes.

### 2.2.14.1. Structure Alignment

Structure alignment is controlled by the `/MEMBER_ALIGNMENT` command-line qualifier or by using the `#pragma member_alignment` preprocessor directive. If `/MEMBER_ALIGNMENT` is specified, or implied by default, the maximum alignment required by any member within the structure determines the structure's alignment. When the structure or union is a member of an array, padding is added to ensure that the size of a record, in bytes, is a multiple of its alignment.

Components of a structure are laid out in memory in the order in which they are declared. The first component has the same address as the entire structure. Padding is inserted between components to satisfy alignment requirements of individual components.

If `/NOMEMBER_ALIGNMENT` is specified, each member of a structure appears at the next byte boundary.

On OpenVMS IA-64 CXX, if `/NOMEMBER_ALIGNMENT` is specified, a zero-length bit field causes the next member to start at the next byte boundary. But on OpenVMS x86-64 zero-length bit field pads to the next alignment boundary determined by its base declared type, regardless of whether the aggregate is packed or not.

### 2.2.14.2. Bit-Fields

If `/MEMBER_ALIGNMENT` is specified, or implied by default, the presence of bit-fields causes the alignment of the whole structure or union to be at least the same as that of the bit-field's base type.

For bit-fields (including zero-length bit-fields) not immediately declared following other bit-fields, their base type imposes the alignment requirements (less than that of type `int`). Within the alignment unit (of the same size as the bit-field's base type), bit-fields are allocated from low order to high order. If a bit-field immediately follows another bit-field, the bits are packed into adjacent space in the same unit, if sufficient space remains; otherwise, padding is inserted at the end of the first bit-field and the second bit-field is put into the next unit.

Bit-fields of base type `char` must be smaller than 8 bits. Bit-fields of base type `short` must be smaller than 16 bits.

### 2.2.14.3. Access Specifiers

The layout of a class is unaffected by the presence of access specifiers.

### 2.2.14.4. Class Subobject Offsets

A class object that has one or more base classes contains instances of its base classes as subobjects. The offsets of nonvirtual base class subobjects are less than the offsets of any data members that are not part of base class subobjects.

The offsets of nonvirtual base classes increase in derivation order. The offset of the first nonvirtual base class subobject of any class is 0. For single inheritance, the address of a class object is always the same as the address of its base class subobject.

If a class has virtual functions, an object of that class contains a pointer to a virtual function table (VFPTR).

If a class has virtual base classes, an object of that class contains a pointer to a virtual base class table (VBPTR).

For a class with no base classes, the offset of a VFPTR or VBPTR is greater than the offset of any data members. Thus, the offset of the first data member of a class with no base classes is 0, which facilitates interoperability with other languages. If the leftmost base class of a subclass has a VFPTR, a VBPTR, or both, and is not virtual, the class and its base class share the table or tables.

The offsets of virtual base class subobjects are greater than the offset of any data member, and increase in the order of derivation of the virtual base classes. In increasing order, a class object contains the following:

1. Nonvirtual base class subobjects
2. Data members
3. VFPTR (if required)
4. VBPTR (if required)
5. Virtual base class subobjects

Consider the following example:

```
class B1
{
    int x[1];
};
class B2 : virtual B1
{
    int y[2];
    virtual int f1();
};
class B3 : virtual B2, virtual B1
{
    int z[3];
    virtual int f2();
};
class D : B3
{
    int a[4];
    virtual int f1(), f2(), f3();
};
```

*Figure 2.1, "Layout of an Object of D Class"* shows the layout of an object of D class for this example.

On OpenVMS x86-64, for a class with no base classes, the offset of a VFPTR is less than the offset of any data members.

To see the layout use this clang option:

```
-cc1 -fdump-record-layouts
```

A class object contains the following:

1. Nonvirtual base class subobjects
2. VFPTR (if required)
3. Data members
4. Virtual base class subobjects

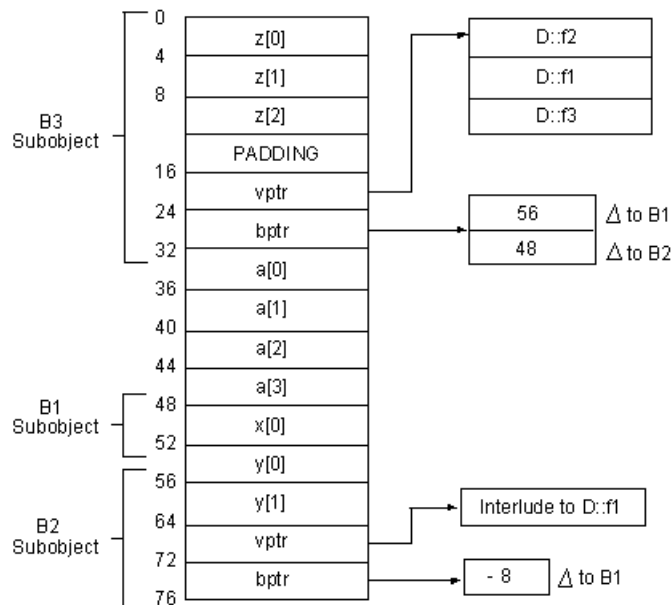
## 2.2.15. Virtual Function and Base Class Tables

The compiler allocates storage for virtual function tables (VTBLs) and base class tables (BTBLs) using the common block extern model. All references to VTBLs and BTBLs share a single copy. (The compiler specifies the local (LCL) PSECT attribute for these tables. Thus, one copy of each table exists for each program image file.) This means that you need not be concerned with the associations of these tables during compilation, and the compiler command switch `+e` supplied in other implementations is not needed for VSI C++ for OpenVMS systems.

## 2.2.16. Multiple Base Classes

Within a class object, base class subobjects are allocated in derivation order; that is, immediate base classes are allocated in the order in which they appear in the class declaration.

**Figure 2.1. Layout of an Object of D Class**



## 2.2.17. Temporary Objects

Under the following conditions, the compiler creates temporary objects for class objects with constructors:

- An object is returned from a function.
- An object is passed as an argument.
- An object is created using the constructor notation.
- A user-defined conversion is implicitly used.

Variations in the compiler generation of such temporary objects can adversely affect their reliability in user programs. The compiler avoids introducing a temporary object whenever it discovers that the temporary object is not needed for accurate compilation. Therefore, you should modify or write your programs so as not to depend on side effects in the constructors or destructors of temporary objects.

### 2.2.17.1. Lifetime of Temporary Objects

Generally the compiler implements destruction of temporary objects at the end of statements. In certain situations, however, temporary objects are destroyed at the end of the expression; they do not persist to the end of the statement. Temporary objects do not persist to the end of statements in expressions that are:

- In operands of built-in conditional operators (`| |` and `&&`)
- In the second or third operand of the ternary operator (`? :`)
- Operands to the built-in comma operator (`,`)

Consider the following example:

```
struct A {
    void print(int i);
    A();
    ~A() { }
};

struct B {
    A* find(int i);
    B(int i);
    B();
    ~B() { }
};

void f() {
    B(8).find(6)->print(6);
    (*B(5).find(3)).print(3);
    return;
}
```

In the first and second statements inside `void f()`, the compiler destroys the temporary object created in evaluating the expressions `B(8)` and `B(5)` after the call to `A::print(int)`.

### 2.2.17.2. Nonconstant Reference Initialization with a Temporary Object

If your program tries to initialize a nonconstant reference with a temporary object, the compiler generates a warning. For example:

```
struct A {
    A(int);
};

void f(A& ar);

void g() {
    f(5); // warning!!
}
```

OpenVMS x86-64 compiler generates an error if you attempt to initialize a temporary object with a nonconstant reference.

### 2.2.17.3. Static Member Functions Selected by Expressions Creating Temporary Objects

When a static member is accessed through a member access operator, the expression on the left side of the dot (.) or right arrow (->) is not evaluated. In such cases, the compiler creates code that calls the static member function to handle the destruction of a class type temporary; the compiler does not create temporary destructor code. For example:

```
struct A {
    ~A();
    static void sf();
};

struct B {
    A operator ()() const;
};

void f () {
    B bobj;
    bobj().sf();           // If 'bobj()' is evaluated, a temporary of
                           // type 'A' is created.
}
```

## 2.2.18. File Inclusion

The `#include` directive inserts external text into the macro stream delivered to the compiler. Programmers often use this directive to include global definitions for use with compiler functions and macros in the program stream.

On OpenVMS systems, the `#include` directive may be nested to a depth determined by the FILLM process quota and by virtual memory restrictions. The compiler imposes no inherent limitation on the nesting level of inclusion.

In C++ source programs, inclusion of both OpenVMS and most UNIX style file specifications is valid. For example, the following is a valid UNIX style file specification:

```
nodename!/device/directory/filename.dat.3
```

The exclamation point (!) separates the node name from the rest of the specification; slash characters (/) separate devices and directories; periods (.) separate file types and file versions. Because one character separates two segments of the file specification, ambiguity can occur.

The `/INCLUDE_DIRECTORY=(pathname,...)` qualifier provides an additional level of search for user-defined include files. Each *pathname* argument can be either a logical name or a legal UNIX style directory in a quoted string. The default is `/NOINCLUDE_DIRECTORY`.

The qualifier provides functionality similar to the `-I` option of the `cxx` command on UNIX systems. This qualifier allows you to specify additional locations to search for files to include. Putting an empty string in the specification prevents the compiler from searching any of the locations it normally searches but directs it to search *only* in locations you identify explicitly on the command line with the /



INCLUDE\_DIRECTORY and /LIBRARY qualifiers (or by way of the specification of the primary source file, depending on the /NESTED\_INCLUDE\_DIRECTORY qualifier).

The basic order for searching depends on the form of the header name (after macro expansion), with additional aspects controlled by other command line qualifiers as well as the presence or absence of logical name definitions. The valid possibilities for names are as follows:

- Enclosed in quotes. For example: "stdio.h"
- Enclosed in angle brackets. For example: <stdio.h>

Unless otherwise defined, searching a location means that the compiler uses the string specifying the location as the default file specification in a call to an RMS system service (that is, a \$SEARCH/\$PARSE) with a primary file specification consisting of the name in the #include (without enclosing delimiters). The search terminates successfully as soon as a file can be opened for reading.

Specifying a null string in the /INCLUDE qualifier causes the compiler to do a non-standard search. This search path is as follows:

1. The current directory (quoted form only)
2. Any directories specified in the /INCLUDE qualifier
3. The directory of the primary input file
4. Text libraries specified on the command line using /LIBRARY

For standard searches, the search order is as follows:

1. Search the current directory (directory of the source being processed). If angle-bracket form, search only if no directories are specified with /INCLUDE\_DIRECTORY.
2. Search the locations specified in the /INCLUDE\_DIRECTORY qualifier (if any).
3. If CXX\$SYSTEM\_INCLUDE is defined as a logical name, search CXX\$SYSTEM\_INCLUDE:.HXX or just CXX\$SYSTEM\_INCLUDE:., depending on the qualifier /ASSUME=NOHEADER\_TYPE\_DEFAULT. If nothing is found, go to step 6.
4. If CXX\$LIBRARY\_INCLUDE is defined as a logical name, CXX\$LIBRARY\_INCLUDE:.HXX or CXX\$LIBRARY\_INCLUDE:., depending on the qualifier /ASSUME=NOHEADER\_TYPE\_DEFAULT. If nothing is found, go to step 6.
5. If /ASSUME=HEADER\_TYPE\_DEFAULT is not specified, search the default list of locations for plain-text copies of compiler header files as follows:

```
SY$COMMON:[CXX$LIB.INCLUDE.CXXL$ANSI_DEF]
SY$COMMON:[CXX$LIB.INCLUDE.DECC$RTLDEF_HXX].HXX
SY$COMMON:[CXX$LIB.INCLUDE.DECC$RTLDEF].H
SY$COMMON:[CXX$LIB.INCLUDE.SY$STARLET_C].H
```

If /ASSUME=HEADER\_TYPE\_DEFAULT is specified, search the default list of locations for plain-text copies of compiler header files as follows:

```
SY$COMMON:[CXX$LIB.INCLUDE.DECC$RTLDEF_HXX].HXX
SY$COMMON:[CXX$LIB.INCLUDE.DECC$RTLDEF].H
SY$COMMON:[CXX$LIB.INCLUDE.SY$STARLET_C].H
```

SYS\$COMMON:[CXX\$LIB.INCLUDE.CXXL\$ANSI\_DEF]

6. Search the directory of the primary input file.
7. If quoted form, and CXX\$USER\_INCLUDE is defined as a logical name, search CXX\$USER\_INCLUDE:.HXX or CXX\$USER\_INCLUDE:., depending on the /ASSUME=NOHEADER\_TYPE\_DEFAULT qualifier.
8. Search the text libraries. Extract the simple file name and file type from the #include specification, and use them to determine a module name for each text library. There are three forms of module names used by the compiler:

a. type stripped:

The file type will be removed from the include file specification to form a library module name. Examples:

#include "foo.h"	Module name "FOO"
#include "foo"	Module name "FOO"
#include "foo"	Module name "FOO"

b. type required:

The file type must be a part of the file name. Examples:

#include "foo.h"	Module name "FOO.H"
#include "foo"	Module name "FOO."
#include "foo"	Module name "FOO."

c. type optional:

First an attempt is made to find a module with the type included in the module name. If this is unsuccessful, an attempt is made with the type stripped from the module name. If this is unsuccessful, the search moves on to the next library.

If /ASSUME=HEADER\_TYPE\_DEFAULT is specified, the following text libraries are searched in this order:

Libraries specified on the command line with the /LIBRARY qualifier (all files, type stripped)  
 CXX\$TEXT\_LIBRARY (all files, type stripped)  
 DECC\$RTLDEF (H files and unspecified files, type stripped)  
 SYS\$STARLET\_C (all files, type stripped)  
 CXXL\$ANSI\_DEF (unspecified files, type stripped)

Otherwise, these text libraries are searched in this order:

Libraries specified on the command line with the /LIBRARY qualifier (all files, type optional)  
 CXX\$TEXT\_LIBRARY (all files, type optional)  
 CXXL\$ANSI\_DEF (all files, type required)  
 DECC\$RTLDEF (H files and unspecified files, type stripped)  
 SYS\$STARLET\_C (all files, type stripped)

## Example 1

```
#include "foo"
```

- a. For each library specified via the /LIBRARY qualifier:
  - Look for "FOO."
  - Look for "FOO"
- b. Look for "FOO." in CXX\$TEXT\_LIBRARY
- c. Look for "FOO" in CXX\$TEXT\_LIBRARY
- d. Look for "FOO." in CXXL\$ANSI\_DEF (Do not look for "FOO" because the type is required as part of the module name)
- e. Look for "FOO" in DECC\$RTLDEF (not "FOO." because the type must not be part of the module name)
- f. Look for "FOO" in SYS\$STARLET\_C (not "FOO." because the type must not be part of the module name)

## Example 2

```
#include "foo.h"
```

- a. For each library specified via the /LIBRARY qualifier:
  - Look for "FOO.H"
  - Look for "FOO"
- b. Look for "FOO.H" in CXX\$TEXT\_LIBRARY
- c. Look for "FOO" in CXX\$TEXT\_LIBRARY
- d. Look for "FOO.H" in CXXL\$ANSI\_DEF (Do not look for "FOO" because the type is required as part of the module name)
- e. Look for "FOO" in DECC\$RTLDEF (not "FOO.H" because the type must not be part of the module name)
- f. Look for "FOO" in SYS\$STARLET\_C (not "FOO.H" because the type must not be part of the module name)
- g. If neither CXX\$LIBRARY\_INCLUDE nor CXX\$SYSTEM\_INCLUDE is defined as a logical name, then search SYS\$LIBRARY:.HXX.

## 2.2.19. Nested Enums and Overloading

The C++ language allows programmers to give distinct functions the same name, and uses either overloading or class scope to differentiate the functions:

```
void f(int);  
void f(int *);  
class C {void f(int);};
```

```
class D {void f(int);};
```

Yet, linkers cannot interpret overloaded parameter types or classes, and they issue error messages if they find more than one definition of any external symbol. C++ compilers, including VSI C++, solve this problem by assigning a unique **mangled name** (also called **type safe linkage name**) to every function. These unique mangled names allow the linker to tell the overloaded functions apart.

The compiler forms a mangled name, in part, by appending an encoding of the parameter types of the function to the function's name, and if the function is a member function, the function name is qualified by the names of the classes within which it is nested.

### Alpha and IA-64 only

For example, for the function declarations at the beginning of this section, the compiler might generate the mangled names `f__Xi`, `f__XPi`, `f__lCXi`, and `f__lDXi` respectively. In these names, `i` means a parameter type was `int`, `P` means “pointer to”, `lC` means nested within class `C`, and `lD` means nested within class `D`.

There is a flaw in the name mangling scheme used by the compiler that can cause problems in uncommon cases. The compiler fails to note in the encoding of an enum type in a mangled name whether the enum type was nested within a class. This can cause distinct overloaded functions to be assigned the same mangled name:

```
struct C1 {enum E {red, blue};};
struct C2 {enum E {red, blue};};

extern "C" int printf(const char *, ...);
void f(C1::E x) {printf("f(C1::E)\n");}
void f(C2::E x) {printf("f(C2::E)\n");}

int main()
{
    f(C1::red);
    f(C2::red);
    return 1;
}
```

In the previous example, the two overloaded functions named `f` differ only in that one takes an argument of enum type `C1::E` and the other takes an argument of enum type `C2::E`. Since the compiler fails to include the names of the classes containing the enum type in the mangled name, both functions have mangled names that indicate the argument type is just `E`. This causes both functions to receive the same mangled name.

In some cases, the compiler detects this problem at compile-time and issues a message that both functions have the same type-safe linkage. In other cases, the compiler issues no message, but the linker complains about duplicate symbol definitions.

If you encounter such problems, you can recompile using the `/DISTINGUISH_NESTED_ENUMS` qualifier (Alpha only). This causes the compiler, when forming a mangled name, to include the name of class or classes within which an enum is nested, thereby preventing different functions from receiving the same mangled name.

Because the `/DISTINGUISH_NESTED_ENUMS` qualifier changes the external symbols the compiler produces, you can get undefined symbol messages from the linker if some modules are compiled with `/DISTINGUISH_NESTED_ENUMS` and some are compiled without it. Because of this, `/DISTINGUISH_NESTED_ENUMS` might make it difficult to link against old object files or libraries of code.

If you compile your code with `/DISTINGUISH_NESTED_ENUMS` and try to link against a library that was compiled without the `/DISTINGUISH_NESTED_ENUMS` qualifier, you receive an undefined symbol message from the linker if you attempt to call a function from the library that takes an argument of a nested enum type. The mangled name of the function in the library will be different from the mangled name your code is using to call the function.

Note that the `/DISTINGUISH_NESTED_ENUMS` qualifier has no meaning on IA-64 systems because it modifies the behavior of programs compiled with `/MODEL=ARM`, and that model is not supported on IA-64 systems.

#### **x86-64 only**

OpenVMS x86-64 CXX compiler uses different mechanism for name mangling. For example, for the function declarations at the beginning of this section, the compiler might generate the mangled names `_Z1fi`, `_Z1fPi`, `_ZN1C1fEi` and `_ZN1D1fEi`. In the second example of this section, OpenVMS x86-64 compiler includes the name of the class containing the enum, thereby it creates different mangled names for two functions "f". Thus the linker message about duplicate symbol definitions is not generated. `/DISTINGUISH_NESTED_ENUMS` qualifier is not supported on x86-64.

## **2.2.20. Guiding Declarations**

A guiding declaration is a function declaration that matches a function template, does not introduce a function definition (implies an instantiation of the template body and not a explicit specialization), and is subject to different argument matching rules than those that apply to the template itself – therefore affecting overload resolution. Consider the following example:

```
template <class T> void f(T) {
    printf("In template f\n");
}

void f(int);

int main() {
    f(0);           // invokes non-template f
    f<>(0.0);       // invokes template f
    return 0;
}

void f(int) {
    printf("In non-template f\n");
}
```

Because there is no concept of guiding declaration in the current version of the C++ International Standard, the function `f` in the example is not regarded as an instance of function template `f`. Furthermore, there are two functions named `f` that take an `int` parameter. A call of `f(0)` would invoke the former, while a call of `f<>(0)` would be required to invoke the latter.

## **2.3. Alternative Tokens**

The compiler supports use of alternative tokens:

#### **`/[no]alternative_tokens`**

Enable use of operator keywords and digraphs to generate tokens as follows:

Operator Keyword	Token
and	&&
and_eq	&=
bitand	&
bitor	
compl	~
not	!
not_eq	!=
or	
or_eq	=
xor	^
xor_eq	^=

Digraph	Token
:>	]
<:	[
%>	}
<%	{
%:	#

OpenVMS x86-64 compiler does not support the use of alternative tokens.

## 2.4. Run-time Type Identification

The compiler emits type information for **run-time type identification** (RTTI) in the object module with the virtual function table, for classes that have virtual function tables.

You can specify the `/[NO]RTTI` qualifier to enable or disable support for RTTI (run-time type identification) features: `dynamic_cast` and `typeid`. Disabling run-time type identification can also save space in your object file because static information to describe polymorphic C++ types is not generated. The default is to enable run-time type information features and generate static information in the object file.

Specifying `/NORTTI` does not disable exception handling.

The type information for the class may include references to the type information for each base class and information on how to convert to each. The `typeid` references are mangled in the form `__T__<class>`.

## 2.5. Message Control and Information Options

### OpenVMS IA-64 and Alpha

The compiler supports the following message control options. The options apply only to warning and informational messages. The `ident` variable is obtained from the error message.

Indicated messages can specify one or more message identifiers `ident` or the message group name `all`.

The default qualifier, `/WARNINGS`, outputs all enabled informational and warning messages. The `/NOWARNINGS` qualifier suppresses both the informational and the warning messages.

Message options are processed and take effect in the following order:

**`/WARNINGS=NOWARNINGS`**

Disable all warnings.

**`/WARNINGS= INFORMATIONALS`**

Enable informationals.

Although `/WARNINGS=INFORMATIONALS` enables most informationals, we recommend using `/WARNINGS=ENABLE=ALL` instead.

**`/WARNINGS= INFORMATIONALS=ALL or (ident, ...)`**

Set the severity of the specified messages to Informational. You can specify `ALL`, which applies only to discretionary messages. The `ALL` option also enables informationals that are disabled by default.

With Version 7.1 of the C++ compiler, `/WARNINGS=INFORMATIONALS=<tag>` no longer enables all other informational messages.

**`/WARNINGS= WARNINGS=ALL or (ident, ...)`**

Set the severity of the specified messages to Warning. You can specify `ALL`, which applies only to discretionary messages.

**`/WARNINGS= [NO]ANSI_ERRORS`**

Issue error messages for all ANSI violations when in `STRICT_ANSI` mode. The default is `/WARNINGS=NOANSI_ERRORS`.

**`/WARNINGS=ERRORS=ALL or (ident, ...)`**

Set the severity of the specified messages to Error. You can specify `ALL`, which applies only to discretionary messages.

**`/WARNINGS=ENABLE=ALL or (ident, ...)`**

Enable all compiler messages, including informational-level messages. Enable specific messages that normally would not be issued when using `/QUIET`. You can also use this option to enable messages disabled with `/WARNINGS=DISABLE`.

**`/WARNINGS=DISABLE=ALL or (ident, ...)`**

Disable message. This can be used for any nonerror message.

**`/QUIET`**

Be more like Version 5.n error reporting. Fewer messages are issued using this option.

This is the default in arm mode (`/STANDARD=ARM`). All other modes default to `/NOQUIET`.

You can use the `/WARNINGS=ENABLE` option with this option to enable specific messages normally disabled using `/QUIET`.

The compiler supports the following message information option, which is disabled by default.

### **`/WARNINGS=[NO]TAGS`**

Display a descriptive tag with each message. "D" indicates that the message is discretionary and that its severity can be changed from the command line or with a pragma. The tag displayed can be used as the `ident` variable in the `/WARNINGS` options.

Example:

```
$ cxx/warnings=tags t.cxx
f() {}
^
%CXX-W-NOSIMPINT, omission of explicit type is nonstandard ("int"
  assumed)
      (D:nosimpint)
at line number 1 in file CXX$:[SMITH]STD.CXX;1

f() {}
.....^
%CXX-W-MISSINGRETURN, non-void function "f" (declared at line 1) should
      return a value (D:missingreturn)
at line number 1 in file CXX$:[SMITH]STD.CXX;1

$ cxx /warnings=(notags,disable=nosimpint) t.cxx

f() {}
.....^
%CXX-W-MISSINGRETURN, non-void function "f" (declared at line 1) should
      return a value
at line number 1 in file CXX$:[SMITH]STD.CXX;1
```

Also see the `#pragma message` preprocessor directive.

## **OpenVMS x86-64**

`[NO]INFORMATIONALS` Has no effect

`[NO]ANSI_ERRORS` Has no effect.

`[NO]TAGS` Has no effect

CXX uses Clang message IDs.

All message IDs should be given to CXX as they are in double quotes to preserve the case. This is true for the keyword **all** as well.

There is a list of warnings in clang that are turned off by default and are enabled with their specific ID or with the keyword **all**.

The VMS-specific warning **cast from long pointer to short pointer will lose data** is off by default. It can be enabled with the ID **may-lose-data** or with **all**.



# Chapter 3. C++ Language Environment

This chapter describes the guidelines and procedures for customizing your language environment. It includes sections on changing your C header files to work with C++, organizing your C++ files, interfacing to other programming languages, and designing upwardly compatible C++ classes.

## 3.1. cname Headers

The C++ compiler implements section 17.4.1.2 – Headers [lib.headers] "C++ Headers for C Library Facilities" of the C++ Standard.

The implementation consists of eighteen <cname> headers defined in C++ Standard:

```
<cassert>   <cctype>   <cerrno>   <cfloat>
<ciso646>   <climits> <locale>   <cmath>
<csetjmp>   <csignal> <cstdlib>  <csddef>
<cstdio>    <cstdlib> <cstring>   <ctime>
<cwchar>   <cwctype>
```

### x86-64 only

```
<ccomplex>
<cfenv>
<cinttypes>
<cstdbool>
<stdint>
<tgmath>
```

**Alpha and IA-64 only:** As required by C++ Standard, the <cname> headers define C names in the std namespace. In /NOPURE\_CNAME mode, the names are also inserted into the global namespace. See the description of the /[NO]PURE\_CNAME compiler qualifier in *Appendix A, "Compiler Command Qualifiers"*. ♦

The <cname> headers are located in the same TLB library that contains C++ standard library and class library headers: SYS\$SHARE:CXX\$ANSI\_DEF.TLB.

---

### Note

On OpenVMS x86-64 CXX compiler, the <cname> headers are not in the TLB file. After the installation these files are located in SYS\$COMMON:[VSICXX\$LIB.INCLUDE.LIB\_CXX] directory.

---

### Note

VSI OpenVMS x86-64 C++ does not support /[NO]PURE\_CNAME mode.

## Examples

```
1.      #include <cstdio>
        void foo() {
```

```
    getchar();    // OK in /NOPURE_CNAME mode
                  // %CXX-E-UNDECLARED in /PURE_CNAME mode
}

2.    #include <cstdio>
    void foo() {
        std::getchar();    // OK in both modes
    }

3.    #include <stdio.h>
    void foo() {
        getchar();        // OK in both modes
        std::getchar();    // OK in both modes
    }
```

## 3.2. Using Existing C Header Files

C header files that already conform to ANSI C standards must be modified slightly to be usable by VSI C++ programs. In particular, be sure to address the following issues:

- Enable the proper linkage for each language.
- Ensure that C++ keywords are not used as identifiers.
- Reconcile any namespace and scoping differences.

The compiler provides some C header files that have been modified to work with C++, including standard ANSI C header files. These headers are in the `SYSS$LIBRARY` directory.

The following sections provide details on how to properly modify your headers.

### 3.2.1. Providing C and C++ Linkage

To modify header files, use conditional compilation and the `extern` specifier.

When programming header files to be used for both C and C++ programs, use the following convention for predefined macros. The system header files also provide an example of correct usage of the predefined macros.

```
#if defined __cplusplus
/* If the functions in this header have C linkage, this
 * will specify linkage for all C++ language compilers.
 */
extern "C" {
#endif

# if defined __DECC || defined __DECCXX
/* If you are using pragmas that are defined only
 * with DEC C and DEC C++, this line is necessary
 * for both C and C++ compilers. A common error
 * is to only have #ifdef __DECC, which causes
 * the compiler to skip the conditionalized
 * code.
 */
/* On x86-64 C++, the same check is this:
 * # if defined __DECC || defined __clang__
 */
```

```
# pragma __extern_model __save
# pragma __extern_model __strict_refdef
extern const char some_definition [];
# pragma __extern_model __restore
# endif

/* ...some data and function definitions go here... */

#ifdef __cplusplus
} /* matches the linkage specification at the beginning. */
#endif
```

See *The Annotated C++ Reference Manual* for more information on linkage specifications.

### 3.2.2. Resolving C++ Keyword Conflicts

If your program uses any of the C++ language keywords as identifiers, you must replace them with nonconflicting identifiers. The list of C++ language keywords can be found in this source: <https://en.cppreference.com/w/cpp/keyword>.

Alternative representation keywords are as follows:

and, and\_eq, bitand, bitor, compl, not, not\_eq, or, or\_eq, xor, xor\_eq

### 3.2.3. Handling Scoping Issues

Distinctions between ANSI C and C++ include slight differences in rules concerning scope. Therefore, you may need to modify some ANSI C header files to use them with C++.

The following sample code fragment generates an error regarding incompatible types, but the root cause is the difference in scope rules between C and C++. In ANSI C, the compiler promotes tag names defined in structure or union declarations to the containing block or file scope. This does not happen in C++.

```
struct Screen {
    struct _XDisplay *display;
};
typedef struct _XDisplay {
    // ...
} Display;

struct Screen s1;
Display      *s2;

main()
{
    s1.display = s2;
}
```

The offending line in this sample is `s1.display = s2`. The types of `s1.display` and `s2` are the same in C but different in C++. You can solve the problem by adding the declaration `struct _XDisplay;` to the beginning of this code fragment, as follows:

```
struct _XDisplay; // this is the added line
struct Screen {
    struct _XDisplay *display;
```

```
};  
typedef struct _XDisplay {  
    // ...  
} Display;  
// ...
```

---

## Note

On OpenVMS x86-64, the CXX compiler does not report an error when compiling the sample code.

---

### 3.2.4. Support for `<stdarg.h>` and `<varargs.h>` Header Files

The C compiler special built-in macros defined in the header files `<stdarg.h>` and `<varargs.h>`. These step through the argument list of a routine.

Programs that take the address of a parameter, and use pointer arithmetic to step through the argument list to obtain the value of other parameters, assume that all arguments reside on the stack and that arguments appear in increasing order. These assumptions are not valid for VSI C++. The macros in `<varargs.h>` can be used only by C functions with old-style definitions that are not legal in C++. To reference variable-length argument lists, use the `<stdarg.h>` header file.

The OpenVMS calling standard mechanism for returning structures larger than 8 bytes by value uses a hidden parameter. The parameter is a pointer to storage in the caller's frame. The `va_count` macro includes this parameter in its count.

## 3.3. Using VSI C++ with Other Languages

The following are suggestions regarding the use of VSI C++ with other languages:

- Passing entities, such as classes, by reference is safest.
- You cannot invoke class member functions from within any language other than C++.
- Every C++ routine that will be called from the other language should be declared in C++ with `extern "C"`. For example:

```
extern "C"  
int myroutine(int, float);
```

The `extern "C"` will cause the routine to have an unmangled name, so that you can refer to it as `myroutine` from a language such as Cobol or Fortran. Otherwise the routine's link name will be mangled into something like `myrout__Xif`.

- If the main routine is defined in the other language, you will probably need to use the other language's command-line interface to perform your link step. To include the appropriate C++ libraries and startup file, you will need to add some arguments to the command line. The most reliable way to determine what is needed is to test with a small C++ program.

## 3.4. Linkage to Non-C++ Code and Data

With linkage specifications, you can both import code and data written in other languages into a VSI C++ program and export VSI C++ code and data for use with other languages.

## 3.5. How to Organize Your C++ Code

This section explains the best way for compiler users to organize an application into files; it assumes that you are using automatic instantiation to instantiate any template classes and functions.

### 3.5.1. Code That Does Not Use Templates

The general rule is to place *declarations* in *header files* and place *definitions* in *library source files*. The following items belong in header files:

- Class declarations
- Global function declarations
- Global data declarations

And the following items belong in library source files:

- Static member data definitions
- Out-of-line member function definitions
- Out-of-line global function definitions
- Global data definitions

Header files should be directly included by modules that need them. Because several modules may include the same header file, a header file must not contain definitions that would generate multiply defined symbols when all the modules are linked together.

Library source files should be compiled individually and then linked into your application. Because each library source file is compiled only once, the definitions it contains will exist in only one object module and multiply defined symbols are thus avoided.

For example, to create a class called “array” you would create the following two files:

**Header file, arrayInt.hxx:**

```
// arrayInt.hxx
#ifndef ARRAY_H
#define ARRAY_H

class arrayInt {
private:
    int curr_size;
    static int max_array_size;
public:
    arrayInt() :curr_size(0) {}
    arrayInt(int);
};

#endif
```

**Library source file, arrayInt.cxx:**

```
// arrayInt.cxx
#include "arrayInt.hxx"
```

```
int array::max_array_size = 256;

arrayInt::arrayInt(int size) : curr_size(size) { ...; }
```

You would then compile the `arrayInt.cxx` library source file using the following command:

```
cxx/include=[.include] arrayInt.cxx
```

The resulting object file could either be linked directly into your application or placed in a library (see *Section 3.5.4, "Creating Libraries"*).

The header file uses **header guards**, which is a technique to prevent multiple inclusion of the same header file.

## 3.5.2. Code That Uses Templates

With the widespread use of templates in C++, determining the proper place to put declarations and definitions becomes more complicated.

The general rule is to place template declarations and definitions in header files, and to place specializations in library source files.

Thus, the following items belong in template declaration files:

- Declarations of global function templates
- Declarations of class templates
- Declarations of global function template specializations
- Declarations of class template specializations

The following items can be placed either in the header file with the corresponding template declaration or in a separate header file that can be implicitly included when needed. This file has the same basename as the corresponding declaration header file, with a suffix that is found by implicit inclusion. For example, if the declaration is in the header file `incl.h`, these corresponding definitions could be in file `incl.cxx`.

- Definitions of out-of-line global function templates
- Definitions of static member data of class templates
- Definitions of out-of-line member functions of class templates

The following must be placed in library source files to prevent multiple definition errors:

- Definitions of global function template specializations
- Definitions of static member data specializations of class templates
- Definitions of out-of-line class member function specializations

These guidelines also apply to nontemplate nested classes inside of template classes.

---

### Note

Do not place definitions of nontemplate class members, nontemplate functions, or global data within template definition files; these must be placed in library source files.

---

All these header files should use header guards, to ensure that they are not included more than once either explicitly or by implicit inclusion.

For example, the array class from *Section 3.5.1, "Code That Does Not Use Templates"*, modified to use templates, would now look as follows:

**Template declaration file, array.hxx:**

```
// array.hxx
#ifndef ARRAY_HXX
#define ARRAY_HXX

template <class T>
class array {
private:
    int curr_size;
    static int max_array_size;
public:
    array() :curr_size(0) {}
    array(int size,const T& value = T());
};

#endif
```

**Template definition file, array.cxx:**

```
// array.cxx
template <class T>
int array<T>::max_array_size = 256;

template <class T>
array<T>::array(int size,const T& value ) { ... ; }
```

Then you would create a source file `myprog.cxx` that uses the array class as follows:

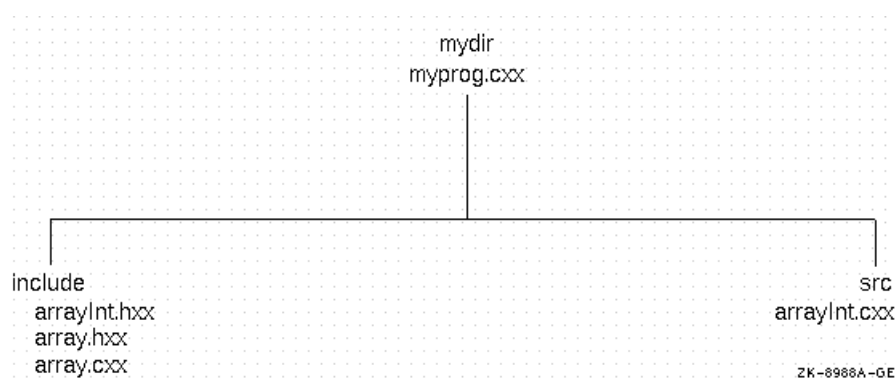
```
// myprog.cxx

#include "array.hxx"

main() {
    array<int> ai;
    // ...
}
```

Figure 3.1, "Placement of Template Declaration and Definition Files" shows the placement of these files.

**Figure 3.1. Placement of Template Declaration and Definition Files**



You would then compile `myprog.cxx` in the `mydir` directory with the following command:

```
cxx/incl=[.include] myprog.cxx
```

In this case, you do not need to create library source files because the static member data and out-of-line members of the array template class are instantiated at the time you compile `myprog.cxx`.

However, you would need to create library source files for the following cases:

- Your template declaration file declares nontemplate classes, global functions, or global data that require definitions in a library source file.
- A template class declares an out-of-line nontemplate friend function whose definition must be placed in a library source file.
- Your template declaration file declares a specialization of a template class whose static member data or out-of-line member function definitions must be placed in a library source file.
- Your template declaration file declares an out-of-line specialization of a template function, whose definition must be placed in a library source file.

---

## Note

On OpenVMS x86-64 CXX, the definition of a template function or class must be included within the header file. The content of the file `array.cxx` should be included in `array.hxx`.

---

## 3.5.3. Summary

Table 3.1, "Declaring and Defining Classes, Functions, and Data" describes where to place declarations and definitions, as discussed in Section 3.5.1, "Code That Does Not Use Templates" and Section 3.5.2, "Code That Uses Templates".

**Table 3.1. Declaring and Defining Classes, Functions, and Data**

Feature	Declaration	Out-of-Line Definition
Class	Header file	
Static member data	Within class declaration	Library source file
Member function	Within class declaration	Library source file
Global function	Header file	Library source file
Global data	Header file	Library source file
Template class	Template declaration file	
Static member data of template class	Within template class declaration	Template definition file
Member function of template class	Within template class declaration	Template definition file
Global template function	Template declaration file	Template definition file
Global, nontemplate friend function of template class	Within template class declaration	Library source file
Specialization of template class	Template declaration file	



Feature	Declaration	Out-of-Line Definition
Specialization of template function	Template declaration file	Library source file

### 3.5.4. Creating Libraries

Libraries are useful for organizing the sources within your application as well as for providing a set of routines for other applications to use. Libraries can be either object libraries or shareable libraries. Use an object library when you want the library code to be contained within an application's image; use shareable libraries when you want multiple applications to share the same library code.

Creating a library from nontemplate code is straightforward: you simply compile each library source file and place the resulting object file in your library.

Creating a library from template code requires that you explicitly request the instantiations that you want to provide in your library.

If you make your library available to other users, you must also supply the corresponding declarations and definitions that are needed at compile time. For nontemplate interfaces, you must supply the header files that declare your classes, functions, and global data. For template interfaces, you must provide your template declaration files as well as your template definition files.

For more information on creating libraries, see the *VSI OpenVMS Command Definition, Librarian, and Message Utilities Manual* and the *VSI OpenVMS Linker Utility Manual*.

## 3.6. Sample Code for Creating OpenVMS Shareable Images (Alpha and IA-64 only)

The SW\_SHR sample code consists of several source modules, a command procedure and this description. Table 3.2, "Shareable Image Example Files" lists each of the constituent modules, which are located in the directory SYS\$COMMON:[SYSHLP.EXAMPLES.CXX] on your system.

The code creates an OpenVMS shareable image called SW\_SHR.EXE that supplies a Stopwatch class identical to the C++ Class Library's Stopwatch class. For detailed information about the Stopwatch class, refer to the *VSI C++ Class Library Reference Manual*, CXX\_CLASSLIB.PS, in the SYS\$COMMON:[SYSHLP.CXX\$HELP] directory.

SW\_SHR also provides an instance of a Stopwatch class named G\_sw that shows how to export a class instance from a shareable image. The exportation occurs in the same way that cout, cin, cerr, and clog are exported from the C++ Class Library shareable image.

**Table 3.2. Shareable Image Example Files**

Module Name	Description
SW_SHARE.HXX	General use macros to make exporting of global data (class instances) from shareable images more transparent to the users of class objects.
SW.HXX	The definition of the Stopwatch class supplied by the shareable image.
SW.CXX	Source associated with the public functions defined in SW.HXX. It also contains the declaration of the global Stopwatch (G_sw) class instance.

Module Name	Description
SW_TEST.CXX	A test of each of the Stopwatch's public access points and also the G_sw class instance.
SW_BUILD.COM	A DCL command procedure used to build both the shareable image and the program.
SW_SHR_ALPHA.OPT	An OpenVMS Linker options file, used on OpenVMS Alpha systems, that contains the SYMBOL_VECTOR entry points.
SW_SHR_IA64.OPT	An OpenVMS Linker options file, used on OpenVMS IA-64 systems, that contains the SYMBOL_VECTOR entry points.

In order to build the example, execute the SW\_BUILD.COM procedure, then run the SW\_TEST.EXE image.

When you create shared images on OpenVMS systems, you must export guard variables for template static data members or for static variables defined in inline functions. These guard variables, which are prefixed by \_\_SDG and \_\_LSG respectively, ensure that static data is initialized only once. You must also export the static variables in inlined functions and template static data members from the shared image so that they have only one definition.

## 3.7. Hints for Designing Upwardly Compatible C++ Classes

If you produce a library of C++ classes and expect to release future revisions of your library, you should consider the upward compatibility of your library. Having your library upwardly compatible makes upgrading to higher versions of your library easier for users. And if you design your library properly from the start, you can accomplish upward compatibility with minimal development costs.

The levels of compatibility discussed in this section are as follows:

1. Source compatibility
2. Link compatibility
3. Run or binary compatibility

The format in which your library ships determines the levels of compatibility that apply:

Library Format	Compatibility Level
Source format	Source compatibility only
Object format	Source and link compatibility
Shareable library format	All three kinds of compatibility

If you break compatibility between releases, you should at least document the incompatible changes and provide hints for upgrading between releases.

### 3.7.1. Source Compatibility

Achieving source compatibility means that users of your library will not have to make any source code changes when they upgrade to your new library release. Their applications will compile cleanly against your updated header files and will have the same run-time behavior as with your previous release.

To maintain source compatibility, you must ensure that existing functions continue to have the same semantics from the user's standpoint. In general, you can make the following changes to your library and still maintain source compatibility:

- Add new data members and classes.
- Add new virtual and nonvirtual functions (as long as they do not change overload resolution of existing calls).
- Loosen protection.
- Change inline functions to out-of-line, and out-of-line functions to inline.
- Change the implementation of functions.
- Add arguments with default values to existing member functions.

### 3.7.2. Link Compatibility

Achieving link compatibility means that users of your library can relink an application against your new object or shareable library and not be required to recompile their sources.

#### What Can Change

To maintain link compatibility, the internal representation of class objects and interfaces must remain constant. In general, you can make the following changes to your library and still maintain link compatibility:

- Change anything that is invisible to the user.
- Change the implementation of an out-of-line function.
- Loosen protection.
- Add a new nonvirtual member function (as long as it does not change overload resolution for existing calls).

#### What Cannot Change

Because the user may be linking object modules from your previous release with object modules from your new release, the layout and size of class objects must be consistent between releases. Any user-visible interfaces must also remain unchanged; even the seemingly innocent change of adding `const` to an existing function will change the mangled name and thus break link compatibility.

The following are changes that you cannot make in your library:

- Add, move, or delete data members.
- Add, move, or delete virtual functions.
- Change the signature of virtual and nonvirtual functions.
- Remove nonvirtual functions.
- Change inline function definitions.

- Change functions from out-of-line to inline.

## Designing Your C++ Classes for Link Compatibility

Although the changes you are allowed to make in your library are severely restricted when you aim for link compatibility, you can take steps to prepare for this and thereby reduce the restrictions. VSI suggests using one of the following design approaches:

- Set aside dummy (reserved-for-future-use) data fields and virtual functions within your classes. This assumes you can foresee how much your classes will grow and change in the future.
- Add a level of indirection to hide your virtual functions and data fields from the user. This lets you add and change data fields and virtual functions without affecting the library user; however, there may be some disadvantages such as in performance. This approach is detailed in *Effective C++*, by Scott Meyers.

### 3.7.3. Run Compatibility

Achieving run compatibility means that users of your library can run an application against your new shareable library and not be required to recompile or relink the application.

This requires that you follow the guidelines for link compatibility as well as any operating system guidelines for shareable libraries. On OpenVMS systems, you need to create an upwardly compatible shareable image using a symbol vector. Refer to the *VSI OpenVMS Linker Utility Manual* for information on creating a shareable image.

# Chapter 4. Porting Applications to IA-64 Systems

This chapter describes some of the differences and restrictions you might encounter when porting a C++ application to an IA-64 system. For a summary of new and changed features supported by this version of the compiler on both OpenVMS Alpha and IA-64 systems, see the Preface of this manual. For any known issues, see the C++ release notes.

VSI C for OpenVMS IA-64 uses a new technology base that differs substantially from VSI C++ for OpenVMS Alpha and VSI C for OpenVMS IA-64. Although a great deal of work has been done to make it highly compatible with VSI C++ for OpenVMS Alpha, there are a number of differences that you will likely notice. Among them are:

- Resource requirements.

Programs will usually use more memory, both at compile time and at run time. See *Section 4.1.2, "Quotas"*.

- Floating-point behaviors.

The default on IA-64 systems is `/FLOAT=IEEE/IEEE_MODE=DENORM_RESULTS`. Consistent use of qualifiers across compilations is required. See *Section 4.1.6, "Floating Point"*.

- Simplified instantiation without repository. See *Section 4.1.9, "Templates"*.
- No inline assembly language. See *Section 4.1.7, "Intrinsics and Builtins"*.
- String literal type change.

For standards-compliance and link compatibility between compiler dialects, ordinary string literals now have the type "array of const char" in all compiler dialects on IA-64 systems in all compiler modes and on Alpha systems in `/MODEL=ANSI` mode.

In `/MODEL=ARM` mode on Alpha systems, string literals are of type "array of char" in all compiler dialects.

## 4.1. Compiler Considerations

This section describes porting considerations for the C++ compiler for OpenVMS IA-64 systems. See *Section 4.2, "Library Changes"* for considerations for the standard library, language run-time support library, and class library.

### 4.1.1. Messages

The move from Alpha systems to IA-64 systems may cause some minor differences in certain compiler diagnostics that are signaled from the code generator. As a result, diagnostics for unreachable code and fetches of uninitialized variables might be different on the two platforms. In addition to a change in message text, some conditions detected on one platform might not be detected on the other.

There have also been some changes in the `/WARNINGS` qualifier for both platforms. These include bug fixes and improved compatibility with the C compiler. For a summary of these changes, see the New and Changed Features section of the Preface.

## 4.1.2. Quotas

The C++ compiler for IA-64 systems is built from a different code base than the C++ compiler for Alpha systems, and that code base is larger than the code base for Alpha. Also, IA-64 images tend to be somewhat larger than Alpha images in general. Image size mostly affects working-set size and the amount of pagefile quota needed to execute an image without exhausting virtual memory. If you find that programs that compile and run successfully on Alpha run out of memory on IA-64 systems (either during compilation or when run), you probably need to increase your pagefile quota. There are no specific guidelines at this time. You might start by doubling the quota that was sufficient on Alpha, and then use a "binary-search" approach to arrive at a better quota value for IA-64 systems (doubling again, or halving the increment, until your biggest programs and compilations have just enough memory, and then adding an appropriate safety margin).

## 4.1.3. Dialect Changes

Some of the compiler dialects (options to the `/STANDARD` qualifier) have been updated to reflect the most recent behaviors of the compilers that the dialect is attempting to match. Other changes involve the removal of less significant or undesirable compatibility features.

## 4.1.4. ABI/Object Model changes

The object model and the name mangling scheme used by the C++ compiler on IA-64 systems are different from those used on Alpha systems (different from both `/MODEL=ARM` and `/MODEL=ANSI`). The IA-64 compiler uses the interface described by the IA-64 Application Binary Interface (ABI).

The C++ compiler has some additional encoding rules that are applied to symbol names after the ABI name mangling is determined. All symbols with C++ linkage have CRC encodings added to the name, are uppercased and shorten to 31 characters if necessary. Since the CRC is computed before the name is uppercased, the symbol name is case-sensitive even though the final name is in uppercase. `/NAMES=AS_IS` and `/NAMES=UPPER` are not applicable to these symbols.

All symbols without C++ linkage will have CRC encodings added if they are longer than 31 characters and `/NAMES=SHORTEN` is specified. Global variables with C++ linkage are treated as if they have non-C++ linkage for compatibility with C and older compilers.

## 4.1.5. Command-Line Qualifiers

This section describes C++ command-line qualifier differences to be aware of on IA-64 systems.

### Qualifiers/Features Not Supported on IA-64 Systems

The following command-line qualifiers and features are not supported on C++ for IA-64 systems, and are diagnosed by default because ignoring them is likely to alter program behavior:

- Comma lists are not supported. Their use provokes a fatal error.
- `/INSTRUCTION_SET=NOFLOATING_POINT` is not available on IA-64 systems. If it is specified, a warning message is issued, and `/INSTRUCTION_SET=FLOATING_POINT` is used.
- `/L_DOUBLE_SIZE=64` is not available on IA-64 systems. If it is specified, a warning message is issued, and `/L_DOUBLE_SIZE=128` is used.

## Changed/Ignored Qualifiers

A number of other qualifiers not supported on IA-64 systems are, by default, silently ignored by the compiler. These qualifiers fall into two groups:

- Qualifiers that should not alter the behavior of a correct program and so, if ignored, should have no visible effect. Qualifiers that enable optimizations typically have this characteristic.
- Qualifiers that might affect program behavior but, if ignored, produce no significant change in the vast majority of programs. Examples of qualifiers in this category are `/NORTTI` (the runtime information is always generated) and `/MODEL=ARM` (the ANSI model is functionally superior, and binary compatibility with existing object code is not an issue for the OpenVMS IA-64 platform).

Two optional compiler messages can be enabled to diagnose most of these cases:

- The `QUALNA` message diagnoses uses of the first group.
- The `QUALCHANGE` message diagnoses uses of the second group.

If you encounter porting problems, compile `/WARN=ENABLE=QUALCHANGE` to determine if a qualifier change might be affecting your application.

If you wish to clean up your build scripts to remove extraneous qualifiers that are not meaningful on IA-64 systems, you can enable the `QUALNA` message.

A list of these qualifiers follows:

- `/ARCHITECTURE=option`

An additional keyword has been added: `ITANIUM2`.

If an Alpha keyword (`EV4`, `EV5`, `EV56`, `PCA56`, `EV6`, `EV68`, `EV7`) is specified for *option*, it is ignored.

- `/ASSUME`

The following `/ASSUME` options are ignored on IA-64 systems and should not cause any behavior changes:

```
NORTTI_CTORVTBLS
NOPOINTERS_TO_GLOBALS
TRUSTED_SHORT_ALIGNMENT
WHOLE_PROGRAM
```

- `/CHECK=UNINITIALIZED_VARIABLES`

This qualifier has no effect in this version of the compiler.

- `/DEBUG`

The following debug options are ignored:

```
/DEBUG=NOSYMBOLS
/DEBUG=NOTRACEBACK
```

- `/DISTINGUISH_NESTED_ENUMS`

This qualifier only modified the behavior of programs compiled with `/MODEL=ARM`. Since that model is not supported on the IA-64 platform, this qualifier is meaningless.

- `/EXCEPTIONS=NOCLEANUP`

The `NOCLEANUP` keyword for the `/EXCEPTIONS` qualifier is ignored.

- `/EXCEPTIONS=IMPLICIT`

The `IMPLICIT` keyword for the `/EXCEPTIONS` qualifier is ignored.

- `/FLOAT`

The default for `/FLOAT` on OpenVMS IA-64 systems is `IEEE_FLOAT`.

See *Section 4.1.6, "Floating Point"* for more information about floating-point behavior on IA-64 systems.

- `/IEEE_MODE`

The default for `/IEEE_MODE` on IA-64 systems is `DENORM_RESULTS`, which generates infinities, denorms, and NaNs without exceptions.

On OpenVMS Alpha systems, the default for `/IEEE_MODE` when using `/FLOAT=IEEE_FLOAT` is `FAST`, which causes a `FATAL` error for exceptional conditions such as divide-by-zero and overflow.

See *Section 4.1.6, "Floating Point"* for more information.

- The `/MODEL=ARM` qualifier is treated the same as the default `/MODEL=ANSI` (except for the optional `QUALCHANGE` diagnostic).

- `/OPTIMIZE`

There are several changes to the `/OPTIMIZE` qualifier:

- On IA-64 systems, for `/OPTIMIZE=INLINE`, the keywords `AUTOMATIC` and `SPEED` do the same thing.

Also, the `ALL` keyword does not necessarily result in every possible call being inlined, as it does on Alpha systems.

- The `/OPTIMIZE=TUNE` qualifier takes a new keyword: `ITANIUM2`, which is the default at this time. If you specify an Alpha keyword, it is ignored.
- The `/OPTIMIZE=UNROLL=n` qualifier is not very useful on IA-64 systems. Because of this, specifying an unroll value greater than 0 is simplified to mean that simple loop unrolling is enabled. On IA-64 systems, the user does not have the ability to control the number of times a loop is unrolled.
- `/OPTIMIZE=LIMIT_INLINE` is ignored.

- `/TEMPLATE`

See *Section 4.1.9, "Templates"* for information on template instantiation.

- `/SHOW=STATISTICS`



The `/SHOW=STATISTICS` qualifier is ignored at this time.

- `/STANDARD=CFRONT`

The `/STANDARD=CFRONT` qualifier is no longer available. If it is specified, the compiler issues a warning message and uses the default dialect, `/STANDARD=ANSI`.

## New Qualifiers

The following command-line qualifier is new for C++:

- `/[NO]PURE_CNAME`

This qualifier affects insertion of the names into the global namespace by `<cname>` headers.

In `/PURE_CNAME` mode, the `<cname>` headers insert the names into the `std` namespace only, as defined by the C++ Standard, and the `__PURE_CNAME` macro is predefined by the compiler.

In `/NOPURE_CNAME` mode, the `<cname>` headers insert the name into the `std` namespace and also into the global namespace.

The default depends on the standard mode:

- In `/STANDARD=STRICT_ANSI` mode, the default is `/PURE_CNAME`.
- In all other standard modes, the default is `/NOPURE_CNAME`.

Inclusion of a `<name.h>` header instead of its `<cname.h>` counterpart (for example, `<stdio.h>` instead of `<cstdio>`) results in inserting names defined in the header into both the `std` namespace and the global namespace. Effectively, this is the same as the inclusion of a `<cname>` header in the `/NOPURE_CNAME` mode.

See *Section 3.1, "cname Headers"* for more information.

## 4.1.6. Floating Point

This section describes floating-point behavior on IA-64 systems.

### IEEE Now the Default

On OpenVMS IA-64 systems, `/FLOAT=IEEE_FLOAT` is the default floating-point representation. IEEE format data is assumed and IEEE floating-point instructions are used. There is no hardware support for floating-point representations other than IEEE, although you can specify the `/FLOAT=D_FLOAT` or `/FLOAT=G_FLOAT` compiler option.

These VAX floating-point formats are supported in the IA-64 compiler by generating run-time code that converts VAX floating-point formats to IEEE format to perform arithmetic operations, and then converts the IEEE result back to the appropriate VAX floating-point format. This imposes additional run-time overhead and some loss of accuracy compared to performing the operations in hardware on Alpha and VAX systems. The software support for the VAX formats is provided to meet an important functional compatibility requirement for certain applications that need to deal with on-disk binary floating-point data.

On IA-64 systems, the default for `/IEEE_MODE` is `DENORM_RESULTS`, which is a change from the default of `/IEEE_MODE=FAST` on Alpha systems. This means that by default, floating-point

operations may silently generate values that print as Infinity or Nan (the industry-standard behavior), instead of issuing a fatal run-time error as they would when using VAX floating-point format or /IEEE\_MODE=FAST. Also, the smallest-magnitude nonzero value in this mode is much smaller because results are allowed to enter the denormal range instead of being flushed to zero as soon as the value is too small to represent with normalization.

The conversion between VAX floating-point formats and IEEE formats on the IA-64 architecture is a transparent process that will not impact most applications. All you need to do is recompile your application. Because IEEE floating-point format is the default, unless your build explicitly specifies VAX floating-point format options, a simple rebuild for IA-64 systems will use the native IEEE formats directly. For the large class of programs that do not directly depend on the VAX formats for correct operation, this is the most desirable way to build for IA-64 systems.

When you compile an OpenVMS application that specifies an option to use VAX floating-point on an IA-64 system, the compiler automatically generates code for converting floating-point formats. Whenever the application performs a sequence of arithmetic operations, this code does the following:

1. Converts VAX floating-point formats to either IEEE single or IEEE double floating-point formats.
2. Performs arithmetic operations in IEEE floating-point arithmetic.
3. Converts the resulting data from IEEE formats back to VAX formats.

Where no arithmetic operations are performed (VAX float fetches followed by stores), no conversion will occur. The code handles such situations as moves.

VAX floating-point formats have the same number of bits and precision as their equivalent IEEE floating-point formats. For most applications, the conversion process will be transparent and, therefore, a non-issue.

In a few cases, arithmetic calculations might have different results because of the following differences between VAX and IEEE formats:

- Values of numbers represented
- Rounding rules
- Exception behavior

These differences might cause problems for applications that do any of the following:

- Depend on exception behavior
- Measure the limits of floating-point behaviors
- Implement algorithms at maximal processor-specific accuracy
- Perform low-level emulations of other floating-point processors
- Use direct equality comparisons between floating-point values, instead of appropriately ranged comparisons (a practice that is extremely vulnerable to changes in compiler version or compiler options, as well as architecture)

You can test an application's behavior with IEEE floating-point values by first compiling it on an OpenVMS Alpha system using /FLOAT=IEEE\_FLOAT/IEEE\_MODE=DENORM.

If that produces acceptable results, then simply build the application on the OpenVMS IA-64 system using the same qualifier.

If you determine that simply recompiling with an `/IEEE_MODE` qualifier is not sufficient because your application depends on the binary representation of floating-point values, then first try building for your IA-64 system by specifying the VAX floating-point option that was in effect for your VAX or Alpha build. This causes the representation seen by your code and on disk to remain unchanged, with some additional runtime cost for the conversions generated by the compiler. If this is not an efficient approach for your application, you can convert VAX floating-point binary data in disk files to IEEE floating-point formats before moving the application to an IA-64 system.

## **`/IEEE_MODE` Notes**

On Alpha systems, the `/IEEE_MODE` qualifier generally has its greatest effect on the generated code of a compilation. When calls are made between functions compiled with different `/IEEE_MODE` qualifiers, each function produces the `/IEEE_MODE` behavior with which it was compiled.

On IA-64 systems, the `/IEEE_MODE` qualifier primarily affects only the setting of a hardware register at program startup. In general, the `/IEEE_MODE` behavior for a given function is controlled by the `/IEEE_MODE` option specified on the compilation that produced the main program: the startup code for the main program sets the hardware register according to the command-line qualifiers used to compile the main program.

When applied to a compilation that does not contain a main program, the `/IEEE_MODE` qualifier does have some effect: it might affect the evaluation of floating-point constant expressions, and it is used to set the `EXCEPTION_MODE` used by the math library for calls from that compilation. But the qualifier has no effect on the exceptional behavior of floating-point calculations generated as inline code for that compilation. Therefore, if floating-point exceptional behavior is important to an application, all of its compilations, including the one containing the main program, should be compiled with the same `/IEEE_MODE` setting.

Even on Alpha systems, the particular setting of `/IEEE_MODE=UNDERFLOW_TO_ZERO` has the following characteristic: its primary effect requires the setting of a runtime status register, and so it needs to be specified on the compilation containing the main program in order to be effective in other compilations.

## **4.1.7. Intrinsics and Builtins**

The C++ built-in functions available on OpenVMS Alpha systems are also available on IA-64 systems, with some differences. *Section B.2, "Built-In Functions for IA-64 Systems (IA-64 only)"* documents these differences and describes the built-in functions that are specific to IA-64 systems.

## **4.1.8. ELF**

On OpenVMS Alpha systems, the C++ compiler uses a proprietary object format specific to OpenVMS.

On OpenVMS IA-64 systems, the compiler generates ELF objects. ELF is an industry standard object format used on many UNIX platforms, including Linux. This change should be transparent to most users; it is primarily of interest to compiler and tools developers. The greatest benefit of this change is that it should make it easier to create development tools that work on OpenVMS and other platforms.

Extensions to ELF have been used as needed to provide functionality unique to OpenVMS. See the *Porting Applications from VSI OpenVMS Alpha to VSI OpenVMS Industry Standard 64 for Integrity Servers* for more information on ELF.

## COMDATS/Group Sections

One feature that ELF provides that is new to OpenVMS is the COMDAT section group — a group of sections in an object file that can be duplicated in one or more other object files. The linker is expected to keep one group and ignore all others. The benefit of this feature is that it permits compilers to generate definitions for symbols for things used in multiple objects without having to worry about creating a single definition in one place. The most notable uses for this feature are templates and inline functions.

### New ELF Type for Weak Symbols

A new Executable and Linkable Format (ELF) type was generated to distinguish between the two types of weak symbol definitions.

For modules with ABI versions equal to 2 (the most common version used by compilers):

- Type STB\_WEAK represents the UNIX-style weak symbol (formerly, the OpenVMS-style weak symbol definition for ABI Version 1 ELF format).
- Type STB\_VMS\_WEAK represents the OpenVMS-style of weak symbol definition.

The Librarian supports both the ELF ABI versions 1 and 2 of the object and image file formats within the same library.

## 4.1.9. Templates

This section describes template instantiation for IA-64 systems.

### Implemented using ELF COMDATS/Groups Sections

The Alpha C++ compiler had numerous models for instantiating templates. Each attempted to solve the issue of how to generate one and only one copy of each template. The use of ELF on OpenVMS IA-64 systems provided the compiler with the additional option of using COMDAT section groups. Since this technique is superior to all the models supported on Alpha, this is the only model supported on IA-64 systems.

In this model, templates are instantiated in a COMDAT section group inside every object module that uses them. This is very similar to the `/TEMPLATE=LOCAL` on Alpha systems, except that when the objects are linked together, the linker removes the duplicate copies. The primary advantage of this technique over `/TEMPLATE=LOCAL` and `/TEMPLATE=IMPLICIT_LOCAL` is the reduction in image size.

A secondary advantage is the elimination of distinct data for each template. For example, if a template maintained a list of elements it created, each module would have a separate copy of the list. This behavior does not conform to the standard. If you are currently using `/TEMPLATE=LOCAL` or `/TEMPLATE=IMPLICIT_LOCAL`, you will likely experience no difficulty from this change.

### Not in Repository

The most visible difference that results from this new instantiation model occurs in models that instantiate templates into the repository (`/TEMPLATE=AUTOMATICALL_REPOSITORY|USED_REPOSITORY`).

With the new model, no repository is needed. Build procedures that use CXXLINK will work transparently. Builds that attempt to manipulate objects in the repository will fail and will need to be

changed. In most cases, the reason for manipulating the repository directly has been eliminated with the new template instantiation model.

Also see *Chapter 6, "Using Templates"*.

## 4.1.10. Exceptions and Condition Handlers

The command-line option `/EXCEPTIONS=NOCLEANUP` is not implemented. As a result, you might see destructors being called during cleanup in code previously compiled with this option.

Exception specifications are not implemented. Exception specifications on routine declarations and definitions are accepted syntactically, but their run-time behavior has not yet been implemented.

### 4.1.10.1. Stack unwinding

According to the C++ Standard, an implementation may or may not unwind the stack before calling `terminate` when no matching handler is found for a thrown exception. On IA-64 systems, the implementation unwinds the stack. On Alpha systems, it does not.

Consider the following program:

```
#include <exception>
#include <cstdio>
#include <cstdlib>
class C {
public:
    C() { std::printf("Created\n"); }
    ~C() { std::printf("Destroyed\n"); }
};
void announce1() {
    std::printf("In terminate\n");
    exit(0);
}
int main() {
    C c;
    std::set_terminate(announce1);
    throw 5;
    return 0;
}
```

For the above program, the output on OpenVMS Alpha and IA-64 systems is:

Alpha:	IA64:
Created	Created
In terminate	Destroyed
	In terminate

### 4.1.10.2. Exceptions Not Caught

The compiler assumes that the only two ways an exception can be propagated into a function are:

- From a throw expression, or
- From a routine call that itself can throw an exception.

As a result of this assumption, some exceptions such as those thrown from a signal handler will not be caught.

### 4.1.10.3. terminate() Incorrectly Called

The C++ IA-64 compiler incorrectly calls `terminate()` when, during unwinding, the destruction of an object results in an exception, even if this exception is caught within the destructor.

For example, consider the following program:

```
extern "C" int printf(const char *,...);
struct killit {
    killit () {}
    ~killit () {
        try {
            throw 11;
        } catch (int i) {
            printf("caught %d\n", i);
        }
    }
};
int main () {
    try {
        killit local;
        throw 33;
    } catch (const int &i) {
        printf("caught int: %d\n", i);
    }
    return 0;
}
```

The expected output for the above example is:

```
caught 11
caught int: 33
```

But the executable produced by the C++ IA-64 compiler calls `terminate()`.

In cases where the expression to be thrown has been evaluated, but before the exception can be caught: if a called user function such as a copy constructor exits through an uncaught exception, then the compiler incorrectly attempts to match this latter exception object type to the handlers in enclosing `try` blocks in succession, instead of calling `terminate()`.

Further, the function `uncaught_exception` returns `FALSE` while in the called user function described above.

For example, consider the following program:

```
extern "C" int printf(const char *,...);
extern "C" int exit(int);
#include <exception>
void announce () {
    printf("Terminated!\n");
    exit(0);
}
class Y {
public:
    Y () { printf ("construct Y\n"); }
    Y(Y &rhs) {
        printf ("copy Y\n");
        printf ("uncaught_exception = %s\n", std::uncaught_exception() ?
            "TRUE" : "FALSE");
    }
}
```

```
        throw 20;
    }
    ~Y () { printf ("destruct Y\n"); }
};

void cxx_func () {
    Y OBJ2;
    printf ("In cxx_func\n");
    try {
        throw OBJ2;
    } catch (const Y &) {
        printf("Caught Y &\n");
    } catch (int i) {
        printf("Caught %d\n", i);
    }
    printf ("leaving cxx_func\n");
}

main () {
    std::set_terminate(announce);
    cxx_func();
    printf ("Leaving main\n");
}
```

The expected output in the above example is:

```
construct Y
In cxx_func
copy Y
uncaught_exception = TRUE
Terminated!
```

But the executable produced by the C++ IA-64 compiler outputs:

```
construct Y
In cxx_func
copy Y
uncaught_exception = FALSE
Caught 20
leaving cxx_func
destruct Y
Leaving main
```

The C++ IA-64 compiler also incorrectly calls `terminate()` when a destructor invoked during stack unwinding exits with an exception that violates its own exception specification, instead of calling `unexpected()`.

Consider the following program:

```
#include <exception>
extern "C" void exit(int);
extern "C" int printf(const char *,...);
void announce2 () {
    printf("announce2: Unexpected!\n");
    exit(0);
}
void announce1 () {
    printf("announce1: Terminated!\n");
    exit(0);
}
```

```
class C {
public:
    C() { printf("C()\n"); }
    ~C() throw() { std::set_unexpected(announce2); printf("~C()\n"); throw
3; }
};
void foo() {
    C c;
    printf("throwing ...\n");
    throw 5;
}
main() {
    std::set_terminate(announce1);
    foo();
}
```

In the above example, the expected output is:

```
C()
throwing ...
~C()
announce2: Unexpected!
```

But the executable produced by the C++ IA-64 compiler outputs:

```
C()
throwing ...
~C()
announce1: Terminated!
```

#### 4.1.10.4. Problem in unexpected() Behavior

When a user-defined `unexpected()` routine throws or rethrows an exception, the compiler incorrectly checks the exception specification of the caller of the routine instead of that of the routine itself, which did not allow the exception in its exception specification.

Consider the following program:

```
#include <exception>
#include <cstdlib>
extern "C" int printf(const char *, ...);
void my_unex() {
    printf("In my unex\n");
    throw;
}
void my_term() {
    printf("In my term\n");
    std::exit(0);
}
void foo() throw() { // spec not checked with second rethrow
    printf("In foo\n");
    throw 7;
}
void bar() throw(int) { // this spec checked with second rethrow
    printf("In bar\n");
    foo();
}
void foo2() throw(std::bad_exception) { // spec not checked with first
    rethrow
```



```
    printf("In foo2\n");
    throw 5;
}
int main() {
    std::set_unexpected(my_unex);
    std::set_terminate(my_term);
    try {
        foo2();
    } catch (int i) {
        printf("Caught %d\n", i);
    } catch (std::bad_exception &) {
        printf("Caught bad_exception\n");
    }
    try {
        bar();
    } catch (int i) {
        printf("Caught %d\n", i);
    } catch (...) {
        printf("Caught ...\n");
    }
    return 0;
}
```

In the above example, expected output is:

```
In foo2
In my unex
Caught bad_exception
In bar
In foo
In my unex
In my term
```

But the compiler produces:

```
In foo2
In my unex
Caught 5
In bar
In foo
In my unex
Caught 7
```

## 4.2. Library Changes

For IA-64 systems, the C++ standard library has been upgraded and organized as a shareable image. All applicable fixes and enhancements done in the C++ standard library for Alpha systems, have been applied to the C++ standard library for IA-64 systems.

The C++ class library on IA-64 systems is based on the same code as the C++ class library on Alpha systems. The major change in the C++ class library for IA-64 systems is the removal of the tasks and complex packages.

### 4.2.1. Library Reorganization

The standard library, language run-time support library, and class library have been reorganized for IA-64 systems.

### 4.2.1.1. Standard Library and Language Run-Time Support Library

On Alpha systems, the C++ standard library and language run-time support library is delivered in an object library, `LIBCXXSTD.OLB`, shipped with the compiler kit.

On IA-64 systems, the C++ standard library and language run-time support library are delivered as separate system shareable images shipped with the base operating system. The names of the images are: `CXXL$RWRTL.EXE` and `CXXL$LANGRTL.EXE`, respectively. The images reside in the `SYSLIBRARY` directory and are installed at system startup. The `LIBCXXSTD.OLB` object library does not exist on IA-64 systems.

### 4.2.1.2. Class Library

On Alpha systems, there are three class library shareable images: `CXXL$011_SHR.EXE`, `CXXL$011_SHRTASK.EXE`, and `CXXL$011_TASK.EXE`.

On IA-64 systems, the C++ class library continues to ship as a system shareable image. Because the tasks and complex packages have been removed, there is only one class library image: `CXXL$011_SHR.EXE`.

## 4.2.2. Language Run-Time Support Library

The language run-time support library no longer validates if a negative value has been specified in a call to operator `new`. Instead, the value is treated as an unsigned value, and an attempt is made to dynamically allocate the specified memory.

## 4.2.3. Class Library

The following class library changes have been made:

- The tasks and complex packages have been removed. The recommended replacements are the `pthread`s routines and complex template class, respectively, from the C++ standard library.
- In the `String` class, the `char* ( )` operator, which converts `String` to a pointer to `char`, has been removed. The `String` class has a `const char* ( )` operator, which can be used instead of the removed one.

## 4.2.4. Standard Library

This section describes changes to the C++ standard library.

### 4.2.4.1. Changes

There are two major changes in the C++ standard library for IA-64 systems as compared with the standard library for Alpha systems:

- The C++ standard library has been upgraded from Version 2.0 of the Rogue Wave C++ Standard Library to Version 3.0.
- The C++ standard library is delivered with the operating system as the installed system shareable image `SYSSHARE:CXXL$RWRTL.EXE`, and also in `STARLET.OLB` in the object form for linking `/NOSYSSHARE`. On IA-64 systems, there is no `LIBCXXSTD.OLB`, which is the object library where the C++ standard library for OpenVMS Alpha resides.

Additional standard library changes, known issues, and platform differences are noted in the following sections.

#### 4.2.4.2. Library Headers

While the change in the library distribution model should be transparent to customers (except that application images are much smaller on IA-64 systems), users on IA-64 systems may find that the new C++ Standard Library is much less forgiving in terms of including all necessary library headers than the old Standard Library.

For example, the following program compiles cleanly on OpenVMS Alpha systems despite the fact that it does not include the `<iostream>` header necessary for the `std::cout` object:

```
#ifndef __USE_STD_Iostream
#define __USE_STD_Iostream
#endif
#include <fstream>
using namespace std;
main() {
    cout << "hello, world";
}
```

However, on OpenVMS IA-64 systems, compilation fails with the following error:

```
%CXX-E-UNDECLARED, identifier "cout" is undefined
```

It is nearly impossible to describe all combinations of library constructs and header files that would compile cleanly on Alpha systems and yet fail to compile on IA-64 systems because a library header required by the C++ standard for a particular construct has not been included. If a program that used to compile cleanly on an Alpha system fails to compile on an IA-64 system, it is always a good idea to check that all necessary library headers are included.

#### 4.2.4.3. Internal Library Headers and Macros

A program that includes internal RW stdlib V2.0 library headers, like `<stddefs>` or `<stdcomp>`, or that uses internal library macros `_RW_*`, will have to be modified because the new C++ standard library does not necessarily have the same internal headers or use the same internal macros as the old one.

#### 4.2.4.4. Known Issues and Restrictions

The following are known issues with C++ for OpenVMS IA-64 systems:

- The C++ Standard Library IOStreams expect floating-point values in the IEEE format, which is the default floating-point format on IA-64 systems. Using the Standard Library IOStreams for processing floating-point values in a format other than IEEE (for example, in a program compiled with the `/FLOAT=G_FLOAT` or `/FLOAT=D_FLOAT` qualifier) is not supported. The C++ class library does not have this restriction.

#### 4.2.4.5. Differences Between Alpha and IA-64 Systems

The following are differences between the IA-64 and Alpha standard libraries:

- On OpenVMS Alpha systems, the following constructors for the C++ standard library classes `strstream` and `ostrstream` initialize `ptr[count-1]` with a null byte:

```
strstream(char *ptr, streamsize count,
          ios_base::openmode mode = ios_base::in | ios_base::out);
```

```
ostream(char *ptr, streamsize count,  
        ios_base::openmode mode = ios_base::out);
```

This initialization is not required by the C++ standard, and on IA-64 systems the C++ standard library does not do it.

- On IA-64 systems, map and multimap containers require the standard-conformant form of allocator class: `allocator<pair<const Key, T>>`.

For example, on Alpha systems, it is possible to declare an object of class multimap as the following, with the second template argument of allocator class omitted:

```
multimap<string, int, less<string>, allocator<string> > x;
```

But for IA-64 systems, this must be changed to:

```
multimap<string, int, less<string>, allocator<pair<const string, int> >  
> x;
```

- On IA-64 systems, the `exception.what()` function reports the module name, and the message text might be different.

For example, an output on Alpha systems:

```
Got an exception: string index out of range in function:  
basic_string::replace(size_t, size_t, size_t, char) position: 100 is  
greater than length: 0
```

An output on IA-64 systems:

```
Got an exception: CSRC:[STDIPF_INCLUDE]STRING.CC;:416:  
basic_string::replace(size_type, size_type, size_type, value_type):  
argument value 100 out of range [0, 0)
```

- On IA-64 systems, iostreams extraction operators truncate out-of-range integer values to the maximum possible value for a given type, and set the failbit for the stream.

For example, consider the following program:

```
#ifndef __USE_STD_Iostream  
#define __USE_STD_Iostream  
#endif  
#include <sstream>  
#include <iostream>  
using namespace std;  
main() {  
    istringstream is("32768"); // SHRT_MAX is 32767  
    short s;  
    is >> s;  
    cout << is.fail() << endl;  
    cout << s << endl;  
}
```

On Alpha systems, this program gives:

```
0  
-32768
```

On IA-64 systems, it gives:

1  
32767

Note that on IA-64 systems, the failbit for the stream is set.

According to the C++ Standard - Template class `num_get` [`lib.locale.num.get`], an input that would have caused `scanf` to report an input failure should result in setting `ios_base::failbit` to `err`. Since on OpenVMS, `scanf` reports an input failure in this case (this is an undefined behavior from the point of view of the C standard), the behavior of the C++ standard library on IA-64 systems is standard-compliant.

- On Alpha systems, the `find` template function is implemented using `operator!=`. On IA-64 systems, this function is implemented using `operator==`, which according to the C++ standard is the operator the `find` function should be using.

Consequently, if no conversion from `*InputIterator` to `T` exists, on Alpha systems the following function can be instantiated only if `operator!=( *InputIterator, T)` exists:

```
find(InputIterator first, InputIterator last, const T& value)
```

On IA-64 systems, however, the function can be instantiated only if `operator==( *InputIterator, T)` exists.

The following program illustrates the difference. If you comment out the line `bool operator!=(S, int);`, the program does not compile on Alpha systems. If you comment out the line `bool operator==(S, int);`, the program does not compile on IA-64 systems. The behavior on IA-64 systems is the standard-conformant behavior.

```
include <algorithm>
#include <vector>
struct S {
    int i;
};
bool operator!=(S, int);
bool operator==(S, int);
void foo() {
    std::vector<S> v;
    std::find(v.begin(), v.end(), 0);
}
```

- On IA-64 systems, an attempt to write into a stream opened for read (`ios::in`), causes the stream `badbit` bit to be set.

On both Alpha and IPF systems, nothing is written into a stream opened for read. However, on Alpha systems, the stream `badbit` bit is not set.

The C++ standard does not provide explicit guidance about what to do in this case. However, the behavior on IA-64 systems is more reasonable—at least there is an indication that something was wrong.

- On IA-64 systems, `reverse_iterator` cannot be instantiated on `vector<bool>::iterator` type.

For example, the following program, which compiles cleanly on Alpha systems, does not compile on IA-64 systems:

```
#include <vector>
```

```
typedef std::reverse_iterator<std::vector<bool>::iterator> ri;
main()
{
    ri::pointer (ri::*foo)() const = &ri::operator->;
}
```

A recently adopted resolution for the library issue 120 has made this construct invalid. See <http://std.dkuug.dk/JTC1/SC22/WG21/docs/lwg-active.html#120> for more details.

- On IA-64 systems, for a random access iterator, `operator-(const random_access_iterator&)` returning `difference_type` must be `const`.

For example, the following program compiles cleanly on Alpha systems. However, on IA-64 systems it compiles only if `// const` is uncommented.

```
#include <algorithm>
template <class T> class randomaccessiterator {
public:
    typedef T value_type;
    typedef int difference_type;
    typedef T* pointer;
    typedef T& reference;
    typedef std::random_access_iterator_tag iterator_category;
    bool operator==(const randomaccessiterator&);
    bool operator!=(const randomaccessiterator&);
    T& operator*() const;
    T* operator->();
    randomaccessiterator& operator++();
    const randomaccessiterator& operator++(difference_type);
    randomaccessiterator& operator-();
    const randomaccessiterator& operator-(difference_type);
    randomaccessiterator& operator+=(difference_type);
    randomaccessiterator& operator+(difference_type);
    randomaccessiterator& operator-=(difference_type);
    randomaccessiterator& operator-(difference_type);
    difference_type operator-(const randomaccessiterator&); // const;
};
struct S {};
typedef randomaccessiterator<S> Iterator;
typedef bool (*Predicate)(Iterator::value_type);
template Iterator std::stable_partition<Iterator, Predicate>(Iterator,
Iterator, Predicate);
```

Table 76 in the C++ standard specifies the requirements for a random access iterator. It says the expression `b - a` must be valid, where `a` and `b` denote values of `X`, the random access iterator. It is not completely clear from the standard whether values of `X` also imply `const` values of `X`, but if the answer is yes, the behavior on IA-64 systems is correct.

- On IA-64 systems, an attempt to call the `strstream.seekg(0)` function for an empty stream (the one whose 'next' pointer is `NULL`) causes the stream failbit to be set.

This is a standard-compliant behavior. Notice that after the failbit is set for the stream, the `strstream.str()` function returns a `NULL` pointer.

- On IA-64 systems, after a call to `string.resize(newsize)`, `string.capacity()` does not necessarily return `newsize`.

While on Alpha systems the `string.capacity()` function returns `newsize`, this is not required by the C++ standard. A program relying on Alpha behavior should be modified to call the `string.size()` function instead.

- On IA-64 systems, there is no overload of `basic_string` class for type `bool`.

Version v3.0 of the Rogue Wave C++ standard library does not have this problematic nonstandard overload. For OpenVMS Alpha, it has been recently removed from the library.

- On IA-64 systems, class `std::fpos` does not have the nonstandard member function `offset()`. You can use `fpos::operator streamoff()` instead. For example:

```
#ifndef __USE_STD_Iostream
#define __USE_STD_Iostream
#endif
#include <sstream>
using namespace std;
void foo() {
    istringstream in("hello, world");
    streamoff offset;
    offset = in.tellg().offset();    // Alpha only
    offset = streamoff(in.tellg()); // either Alpha or IPF
}
```

- On OpenVMS Alpha systems, in the default built-in C locale, the monetary facets use values typically found in the `en_US` locale (English in the United States). For example, on Alpha the default national currency string is "\$". On IA-64 systems, in any locale, including the C locale, the monetary facets use values defined by the locale.

Consider the following sample program:

```
#ifndef __USE_STD_Iostream
#define __USE_STD_Iostream
#endif
#include <iostream>
#include <locale>
#include <stdexcept>
#include <stdlib.h>
#if defined(__osf__) || defined(__vms)
#   define UK_LOCALE "en_GB.ISO8859-1"
#elif defined(__linux)
#   define UK_LOCALE "en_GB"
#else
#   error unknown platform
#endif
using namespace std;
void outputSym(ostream& os) {
    locale loc = os.getloc();
    const moneypunct<char, false>& mpunct =
        use_facet<moneypunct<char, false>>(loc);
    os << "currency symbol is: " << mpunct.curr_symbol() << endl;
}
```

This program prints two lines: the national currency symbol in the C locale and the national currency symbol in the `en_GB` locale (English in Great Britain).

- Consider a program using the C++ Standard Library IOSTREAMS, like `x.cxx` below, that writes to `cout`, but not to `cerr` or `clog`:

```
x.cxx
-----
#ifndef __USE_STD_Iostream
#define __USE_STD_Iostream
#endif
#include <iostream>
main() {
    std::cout << "hello, world" << std::endl;
}
```

On OpenVMS Alpha systems, if such a program is invoked with `SY$OUTPUT` redirected to a file and `SY$ERROR` defined as `SY$OUTPUT`, a single version of the output file is created.

On IA-64 systems, by default, two versions of the file are created: one for `SY$OUTPUT` and another for `SY$ERROR`. To get Alpha behavior on an IA-64 system, define logical name `DECC$COMMON_STDERR_STDOUT` to `ENABLE`. The following command file shows the definition:

```
x.com
-----
$ if f$search("x.dat") .nes. "" then delete x.dat;*
$ define/user sys$output x.dat
$ define/user sys$error sys$output
$ if f$getsy("arch_name") .eqs. "IA64" then -
    define/user decc$common_stderr_stdout enable
$ run x.exe
```

## 4.3. CXXLINK Changes

Because of changes in the architecture on IA-64 systems, CXXLINK plays a much smaller role. Its only remaining purpose is to provide human readable (demangled) names for mangled C++ names in diagnostics generated by the linker.

Specific changes are:

- There is no `LIBCXXSTD.OLB`

On IA-64 systems, there is no `LIBCXXSTD.OLB`, which is the object library where the C++ standard library for OpenVMS Alpha resides. See *Section 4.2.4, "Standard Library"* for more information.

- The library is reorganized

The C++ libraries have been reorganized and incorporated into the base system. CXXLINK no longer needs to specify any C++ libraries when invoking the system linker. See *Section 4.2, "Library Changes"* for more information.

- There are no templates in a repository

With the new template instantiation model, objects are no longer placed in a repository. Therefore, CXXLINK no longer needs to look at the repositories for templates. See *Section 4.1.9, "Templates"* for more information.



# Chapter 5. Porting Applications from IA-64 to x86-64 Systems

This kit includes the VSI C++ x86-64 compiler. This compiler runs on OpenVMS x86-64 and generates code for OpenVMS x86-64. The compiler is based on the LLVM Clang compiler with additional OpenVMS features. You can learn more about Clang at <https://clang.llvm.org/>.

## 5.1. Changes from Prior Compilers

The PCSI package provides two C++ compilers, the CXX demangling tool, C++ run-time libraries, and C++ system headers:

1. By default, the operators `new` and `new[ ]` return 64-bit addresses that will not fit into 32-bit pointers. This is a change from the V10.1-1 compiler that always allocated memory in 32-bit heap. Compilations that use `/POINTER_SIZE=32` on the command line will allocate memory from the 32-bit heap, but compilations that do not use `/POINTER_SIZE` or those that use `/POINTER_SIZE=64` will allocate memory from the 64-bit heap. The `#pragma pointer_size` also changes the behavior of the `new( )` operator and it allocates memory from the 32-bit or 64-bit space depending on the pragma option.

For programs that revert back to 32-bit memory allocation with `/POINTER_SIZE=32`, ensure that all systems have the newest `LIBCXX` and `LIBCXXABI` libraries installed on target systems. Currently, these updated RTLs are only available with the C++ kit, so you must install C++ on all target systems, even those that will not be used for development. The updated RTLs will be included in a future update for OpenVMS V9.2-2.

2. The `/LIST` qualifier is now supported. The compiler supports most of the `/SHOW` keywords (like on IA-64) and creates a listing file that has a very similar look and feel to the listing files created by the Alpha and IA-64 compilers.
3. `LIB$ESTABLISH` built-in is fully supported by CXX.
4. The allocation of objects of `std::string` is now based on the current pointer size setting. The default allocator for `std::string` will be automatically changed to the allocator appropriate for the 32-bit address space based on the current `/POINTER_SIZE` or `#pragma [required_]pointer_size` setting. When the pointer size is set to 32 bits, the object will be allocated in the 32-bit memory to ensure that `std::string::c_str( )` and `std::string::data( )` return valid 32-bit pointer values.
5. The ability to do source-level debugging in the OpenVMS debugger is now supported. When debugging, users need to enter `SET SOURCE` before printing a line from a file.

Every kit contains a log file that lists the differences compared to the previous release:

```
$ type SYS$HELP:CXX.CHANGELOG
```

The compiler behaves very much like the Linux version of the Clang compiler in terms of language features. The primary differences is the support of the OpenVMS-specific features, pragmas, and predefined symbols.

VSI C++ predefines common OpenVMS symbols much like the IA-64 C++ compiler (for example, `VMS`, `__VMS`, `__vms`, `__INITIAL_POINTER_SIZE`), as well as the industry standard symbols

such as `__x86_64` and `__x86_64__`. VSI C++ compiler does not define the `__DECCXX_VER` and `__DECC_VER` macros. Instead, it defines the `__VSIC_VER` and `__VSICXX_VER` macros. You can use these macros to test whether the current compiler version is newer than another version. In order to get the C++ standard version, you need to use `__cplusplus` value. When you compile in C mode with Clang, please use `__STDC_VERSION__` to get the C version.

VSI C++ also defines the `_USE_STD_STAT` macro by default which is not defined in IA-64 C++. To undefine this macro from the command line, use the `/UNDEFINE=_USE_STD_STAT` qualifier for CXX or the `-U_USE_STD_STAT` option for Clang.

Unlike a traditional UNIX compiler which "compiles and links" with a single command, the compiler on OpenVMS only compiles (i.e., the equivalent of the `-c` option on UNIX).

There are two RTLs to support C++ (LIBCXX and LIBCXXABI). C++ provides two versions of these libraries – static and shared. They are copied to the `SYS$COMMON:[SYSLIB]` directory during the installation. Shared libraries are also inserted into `SYS$LIBRARY:IMAGELIB.OLB`, so if a program needs to be linked against shared libraries, they will be found automatically. However, if a program needs to be linked against static libraries, you must provide them explicitly, or you can use the `SYS$COMMON:[SYSHLP.EXAMPLES]CXX.OPT` (or `SYS$EXAMPLES:CXX.OPT`) file.

For example:

```
// HW.CXX
#include <iostream>

int main()
{
    std::cout << "Hello World!\n";
    return 0;
}

$ CXX HW.CXX
$ LINK HW ! Link against installed shared libraries
$ RUN HW
Hello World!
$ LINK HW,SYS$EXAMPLES:CXX/OPT ! Link against static libraries
$ RUN HW
Hello World!
```

The OpenVMS x86-64 linker places code into the 64-bit address by default (the default on Alpha and IA-64 was to place code into 32-bit address space). Programs should not notice the difference. The linker creates small trampolines in the 32-bit address space, so the address of a routine will still fit into a 32-bit variable.

## 5.2. OpenVMS-Specific Pragmas

Compilers have been extended to support the following OpenVMS-specific pragmas:

```
#pragma pointer_size [options]
#pragma required_pointer_size [options]
#pragma [no]member_alignment [options]
#pragma extern_model [options]
#pragma extern_prefix [options]
#pragma include_directory <string-literal>
#pragma message [option] ("message-list")
```

Other OpenVMS pragmas are processed, however they only have partial/limited support at the moment. The `#pragma` message is supported, but the names of the error messages on IA-64 and x86-64 are different, so they need to be modified.

The `#pragma pointer_size` is active only when the DCL qualifier `/POINTER_SIZE` (or `-pointer-size` option for the foreign CLANG command) is given. This matches the behavior of the VSI C++ IA-64 compiler.

Neither `/POINTER_SIZE` (`-pointer-size`) nor `#pragma [required_]pointer_size` has any effect on `vptr`. The size of the virtual pointer is always 64 bit.

The option provided to `#pragma nomember_alignment [option]` determines the base alignment of the structure. If provided with the appropriate alignment, the attribute is set on the structure declaration.

There are some differences from the IA-64 CXX member alignment:

- In IA-64 CXX:

```
struct
/*
** This directive does not change the alignment of s1 because we have
** already started the struct.
*/
#pragma nomember_alignment
{
    ...
} s1;
```

On OpenVMS x86-64, it does change the alignment. It is best to use the `pragma` prior to the `struct` definition.

- In IA-64 CXX, the `#pragma pack` cancels the base alignment defined by `#pragma nomember_alignment <base_alignment>`, but on OpenVMS x86-64, `#pragma pack` has no effect on base alignment.
- In IA-64 CXX, if the aggregate is packed, a zero-length bit field causes the next member to start at the next byte boundary.

On OpenVMS x86-64, the zero-length bit field pads to the next alignment boundary determined by its declared base type, regardless of whether the aggregate is packed or not.

The compiler supports `#pragma extern_model`, which means that the `strict_refdef`, `common_block`, `relaxed_refdef`, `globalvalue`, `save`, and `restore` options are supported.

The following attributes are available:

```
gbl lcl
shr noshr
wrt nowrt
ovr con
exe noexe
vec novec
```

The following alignments are available:

```
byte
```

```
word
long
quad
octa
```

The IA-64 compiler provided many header files that are not STL standard files. The x86-64 installation adds hard links with .HXX extensions for all STL standard files and .H hard links for those of them that conflict with the CRT headers.

The files like

```
stream.h(xx)
generic.h(xx)
strstream.hxx
messages.hxx
cxx1.hxx
```

were provided for the IA-64 CXX internal use only and not for compiler users. If you for some reason include these files, you must update your code to be able to compile with the x86-64 CXX compiler based on Clang.

An OpenVMS style `#pragma message` is also available. Currently, the compiler only supports the following format:

```
#pragma message [option] ("message-list")
```

The `[option]` parameter must be one of the following keywords:

Keyword	Meaning
enable	Enables issuance of messages specified in the message list.
disable	Disables issuance of messages specified in the message list.
error	Sets the severity of each message in the message list to Error.
fatal	Sets the severity of each message in the message list to Fatal.
informational/warning	Sets the severity of each message in the message list to Warning.
save	Saves the current state of the compiler messages.
restore	Restores the saved state of the compiler messages.

## Example:

```
// example.cpp
#pragma message enable ("unused-variable")
#pragma message disable ("return-type implicitly-unsigned-literal")
int foo() {
    long long a = 12341234123412341234;
    int b = a;
}
```

With the example above, you should get something like this:

```
warning: unused variable 'a' [-Wunused-variable]
```

The values for the `message-list` is the name following the message severity code letter. In this example, the `unused-variable` message is enabled, while `return-type` and `implicitly-unsigned-literal` are disabled. The values in the `message-list` should be separated by spaces.

The IA-64 C++ compiler message identifiers are not supported and are silently ignored. You should use Clang's respective message IDs. Note that it is not possible to reduce message severity to warning after it was set to error or fatal, but it is possible to reduce from fatal to error.

## 5.3. TLB And Headers

The C++ compiler allows to search and use text libraries (TLB) with the **/LIBRARY** qualifier and with automatic searches for headers performed by the compiler. However, unlike in the C++ compiler on IA-64, some of the headers on x86-64 are expanded into separate files. The installation directory for the C++ standard library headers is `SYSS$COMMON:[VSICXX$LIB.INCLUDE.LIB_CXX.INCLUDE]`.

Both the **CXX** DCL command and the **CLANG** DCL symbol, defined by the `SYSS$EXAMPLES:CXX$SETUP.COM` command file, know the location of these headers.

## 5.4. Prologue/Epilogue Files

Both Clang and CXX automatically process user-supplied prologue and epilogue files just like the IA-64 compiler.

### 5.4.1. Using Prologue/Epilogue Files

Prologue/epilogue file are processed in the following way:

1. When the compiler encounters an `#include` preprocessing directive, it determines the location of the file or text library module to be included. Then, it checks if one or both of the following specially named files or modules exist in the same location as the included file:

```
__DECC_INCLUDE_PROLOGUE.H  
__DECC_INCLUDE_EPILOGUE.H
```

The location is the OpenVMS directory containing the included file or the text library file containing the included module. In case of a text library, module names should not include the `.H` suffix.

2. If the prologue and epilogue files do exist in the same location as the included file, then the content of each is read into memory.
3. The text of the prologue file is processed just before the text of the file specified by `#include`.
4. The text of the epilogue file is processed just after the text of the file specified by `#include`.
5. Subsequent `#includes` that refer to files from the same location use the saved text from any prologue/epilogue file found there.

## 5.5. Differences Between C++ on OpenVMS IA-64 and OpenVMS x86-64

- The datatypes `long`, `size_t`, `nullptr_t`, `ptrdiff_t` are 64-bits wide on OpenVMS x86-64 but only 32-bits wide on OpenVMS IA-64.
- The default size for pointers is 64 bits on OpenVMS x86-64 but only 32 bits on OpenVMS IA-64. You can use the command-line option `-pointer-size` for Clang and **/POINTER\_SIZE** qualifier for **CXX** to change the default size of pointers.

- The compiler does not automatically upcase external names like all other OpenVMS compilers. There is a `-names` command-line option for Clang and `/NAMES` qualifier for **CXX** and their default is `as_is`.
- The compiler does not automatically truncate external names that are longer than 31 characters. External names can be any length. There are symbol length limits in the `LIBRARIAN` and `LINKER` options files, but in general, symbol lengths do not matter in `LINKER`. The `/NAMES=TRUNCATED` option can be used to revert to the IA-64 C++ behavior.
- The compiler does not support passing non-trivial arguments with no corresponding parameter.

Example:

```
// Non-trivial type.
struct O {
    int a;  int b;  int c;
    ~O() {}
};

void hn(...) {}

int main()
{
    O o;
    hn(o);
    return 0;
}
```

In the example above, the C++ compiler will generate the error message similar to the following:

```
error: cannot pass object of non-trivial type 'O' through variadic
function; call will abort at runtime [-Wnon-pod-varargs]
```

You can suspend this error with `-Wno-non-pod-varargs`, but the program will abort at runtime.

- Some well-known function calls may be optimized away.

Example:

```
#include <stdio.h>
#include <stdlib.h>
extern "C" {
    double ceil(double a) { printf("User defined\n"); return 0; }
}

int main() {
    printf("%f\n", ceil(5.6)); // user-defined won't be called, ceil call
                              optimized out

    volatile double a;
    printf("%f\n", ceil(a));
    return 0;
}
```

In this case, Clang puts the result of the first `ceil` function call directly in the place where it is called. And if first call never happens, you will get the next result.

Result:

```
6.000000
User defined
0.000000
```

- The x86-64 **CXX** command does not support comma-separated lists for source files, it only accepts one source file at a time.
- `#pragma required_pointer_size` directive affects LIBCXX's allocating (not placement) operator new behavior. The operator new allocates memory with a 32-bit or 64-bit address, depending on the pragma option.

Example:

```
int main() {
    #pragma required_pointer_size short
    // here the operator new allocates 32bit address memory
    int* p1 = new int;
    delete p1;

    #pragma required_pointer_size long
    // here the operator new allocates 64bit address memory
    int* p2 = new int;
    delete p2;
}
```

- `chf64$signal_array*` thrown by `LIB$SIGNAL` call cannot be caught with the catch block of the `chf$64signal_array&` param type. It can be caught directly with the `catch( chf $64signal_array* )` or `catch( ... )` block.
- The allocation of objects of `std::string` is now based on the current pointer size setting. The default allocator for `std::string` will automatically change based on the current `/POINTER_SIZE` or `#pragma [required_]pointer_size` setting. When the pointer size is set to 32 bits, the object will be allocated in 32-bit memory to ensure that `std::string::c_str()` and `std::string::data()` return valid 32-bit pointer values.

## 5.6. SYS\$STARTUP:CXX\$STARTUP.COM Startup File

It contains commands that can be executed after the product install procedure has been run and at startup to allow for the best compilation performance. You may want to invoke this command file from your system's site-specific startup file. This command file does not have to be invoked for the correct operation of VSI C++.

## 5.7. Using the Clang Command Line

Clang is sensitive to input file extensions. Clang is both a C and a C++ compiler. If you compile a file with the ".C" extension, Clang enters "C mode". If you compile with the ".CPP" (or ".CXX") extension, it will enter "C++ mode". In C-mode, C++ features and libs (even STL) are not available. But there is an `-x` command-line option that can force Clang to switch to the specified language mode. The following command will compile `a.c` as C++ code:

```
$ clang -x c++ a.c
```

The command-line options are also case-sensitive. However, due to the default parsing rules for upcasing arguments in DCL, you will get errors such as:

```
$ clang except.cpp -Wall -I disk2:[000000]
clang: error: unknown argument '-wall'; did you mean '-Wall'?
clang: error: unknown argument: '-i'
```

The issue here is that DCL with traditional parsing will upcase all the arguments and then the CRTL will downcase all the arguments. You can prevent DCL from upcasing by using double-quotes on the `-Wall` and `-I` command-line options.

Alternatively, you can prevent DCL from upcasing and CRTL from downcasing with these definitions (you can put them in your LOGIN.COM):

```
$ set process /parse=extended
$ define/nolog DECC$ARGV_PARSE_STYLE ENABLE
$ define/nolog DECC$EFS_CASE_PRESERVE ENABLE
$ define/nolog DECC$EFS_CHARSET ENABLE
```

Note, however, that these changes may impact other OpenVMS commands and programs.

Clang accepts multiple source files in one command line. For example:

```
$ clang a.cpp b.cpp
```

Clang allows to compile C files as well, according to C99 standard compiling and linking the example below ends with an undefined symbol.

Example:

```
$type test.c
#include <stdio.h>
inline int sumx( int x , int y ) { return 0; }
int main() {
    int x = 8;
    int y = 7;
    printf( "sum = %d\n" , sumx(x,y) );
}
$ clang test.c
$ link test
%ILINK-W-NUDFSyms, 1 undefined symbol:
%ILINK-I-UDFSYM, sumx
%ILINK-W-USEUNDEF, undefined symbol sumx referenced
```

Here are possible ways to fix this problem:

- Change `sumx` to a static inline function. This is usually the right solution if only one translation unit needs to use the function. static inline functions are always resolved within the translation unit, so you won't have to add a non-inline definition of the function elsewhere in your program.
- Remove the `inline` keyword from this definition of `sumx`. The `inline` keyword is not required for a function to be inlined, nor does it guarantee that it will be. Clang treats it as a mild suggestion from the programmer.
- Provide an external (non-inline) definition of `sumx` somewhere else in your program. The two definitions must be equivalent!



- Compile in the GNU C89 dialect by adding `-std=gnu89` to the set of Clang options. This option is only recommended if the program source cannot be changed or if the program also relies on additional C89-specific behavior that cannot be changed.

## 5.8. Supported and Not Supported DCL Qualifiers

The following table shows the current set of supported DCL qualifiers. Support for the remaining qualifiers will be added in a future release.

OpenVMS C++ for x86-64 supports a subset of qualifiers from the IA-64 C++ compiler plus additional qualifiers that are unique for x86-64.

- `/ALTERNATIV_TOKENS`
- `/ANSI_ALIAS`
- `/ARCHITECTURE`
- `/ASSUME`
- `/BE_DUMPS`
- `/BOTH_CASE`
- `/BREAKPOINTS`
- `/CHECK`
- `/CLANG`
- `/COMMENTS`
- `/DEBUG`
- `/DEFINE`
- `/DIAGNOSTICS`
- `/DISTINGUISH_NESTED_ENUMS`
- `/DUMPS`
- `/ENDIAN`
- `/ERROR_LIMIT`
- `/EXCEPTIONS`
- `/EXTERN_MODEL`
- `/EXPORT_SYMBOLS`
- `/FE_DUMP`
- `/FIRST_INCLUDE`

- /FLOAT
- /GEMDEBUG
- /G\_FLOAT
- /GRANULARITY
- /IEEE\_MODE /IMPLICIT\_INCLUDE
- /INCLUDE\_DIRECTORY
- /INSTRUCTION\_SET
- /LIBRARY
- /LIST
- /L\_DOUBLE\_SIZE
- /LINE\_DIRECTIVE
- /LOOKUP
- /MACHINE\_CODE /MAIN
- /MEMBER\_ALIGNMENT /MODEL
- /MMS\_DEPENDENCIES /NAMES
- /NESTED\_INCLUDE\_DIRECTORY
- /OBJECT
- /OPTIMIZE
- /OS\_VERSION
- /PENDING\_INSTANTIATIONS
- /POINTER\_SIZE
- /PREFIX\_LIBRARY\_ENTRIES
- /PREPROCESS\_ONLY
- /PSECT\_MODEL
- /PURE\_CNAME
- /QUIET
- /REENTRANCY
- /REPOSITORY
- /ROUNDING\_MODE

- `/RTTI /SHARE_GLOBALS`
- `/SHOW`
- `/STACK_CHECK`
- `/STANDARD`
- `/SWITCHES`
- `/TEMPLATE_DEFINE`
- `/TRACEPOINTS`
- `/UNDEFINE`
- `/UNSIGNED_CHAR`
- `/USING_STD`
- `/VERBOSE`
- `/VERSION`
- `/WARNINGS /XREF`

## 5.9. Using Clang Command Options from DCL Command Line

A new qualifier has been added that allows you to pass the Clang command-line options when there is no equivalent DCL qualifier.

```
/CLANG=(quoted_string[,...])
```

This qualifier takes Clang options and passes them to the Clang driver. It is important to specify them in double quotes and separate them with a comma.

Instead of

```
CXX /CLANG=(-Wall, "-D__macro1 -D__MACRO2") foo.cxx
```

specify

```
CXX /CLANG=("-Wall", "-D__macro1", "-D__MACRO2") foo.cxx
```

## 5.10. Mapping Clang Command Options to DCL Command Options

This section shows Clang options that are similar to **CXX** DCL qualifiers.

**/DEFINE**

`-D` flag, so **/DEFINE=TRUE** becomes `-DTRUE` which results to `#define TRUE 1`.

**/INCLUDE\_DIRECTORY**

`-I <directory>` – add directory to include search path.

The compiler is extended to support files lookup at predefined logicals locations.

Example:

```
// DISK:[SOURCES]INC.CPP
#include <SYS/INC.HPP>
int main()
{
    f();
}

// DISK:[HEADERS]INC.HPP
void f() {};
```

To compile INC.CPP, it is enough to define the corresponding SYS logical:

```
$ DEFINE SYS DISK:[HEADERS]
```

And then compile INC.CPP:

```
$ SET DEF DISK:[SOURCES]
$ CXX INC.CPP
```

The CXX\$SYSTEM\_INCLUDE, CXX\$LIBRARY\_INCLUDE, and CXX\$USER\_INCLUDE logical names are supported.

If some of them are defined, then the compiler will also do the header search in the directories mentioned by the logicals in the same order as listed above.

Note that CXX\$USER\_INCLUDE will also impact angle-bracket include directives, which is NOT the same behavior as in IA-64 CXX. The **/ASSUME** qualifier is not supported yet.

**/POINTER\_SIZE, /NOPOINTER\_SIZE**

`-no-pointer-size`

- Disables processing of `#pragma pointer_size`
- Predefines the preprocessor macro `__INITIAL_POINTER_SIZE` to 0
- Note, that the initial default pointer size is 64-bit

On Alpha and IA-64, **/NOPOINTER\_SIZE** instructs the compiler to assume that all pointers are 32-bit pointers.

`-pointer-size={long|short|64|32|argv64}`

- `argv64` means:
  - The main argument `argv` will be an array of 64-bit pointers. The default is an array of 32-bit pointers.
  - Enables processing of `#pragma pointer_size`

- Sets the initial default pointer size to 64-bit for translation unit
- Predefines the preprocessor macro `__INITIAL_POINTER_SIZE` to 64
- `long` or 64 means:
  - Enables processing of `#pragma pointer_size`
  - Sets the initial default pointer size to 64-bit for translation unit
  - Predefines the preprocessor macro `__INITIAL_POINTER_SIZE` to 64
- `short` or 32 means:
  - Enables processing of `#pragma pointer_size`
  - Sets the initial default pointer size to 32-bit for translation unit
  - Predefines the preprocessor macro `__INITIAL_POINTER_SIZE` to 32

The default is `-no-pointer-size` option.

#### **`/NAMES=(UPPERCASE,AS_IS)`**

`-names={uppercase|as_is}` option.

This option controls the conversion of external symbols to the specified case. Two possible options are `uppercase` and `as_is`:

- `uppercase` – uppercases all external symbols in translation unit.
- `as_is` – leaves them as they are. This is default.

#### **`/NAMES=(TRUNCATED,SHORTENED)`**

`-names2={truncated|shortened}` option.

This option controls whether the external names longer than 31 characters get truncated or shortened. Two possible options are:

- `truncated` – Truncates long external names to first 31 characters.
- `shortened` – shortens long external names.

A shortened name consists of the first 23 characters of the name followed by a 7-character Cyclic Redundancy Check (CRC), computed by looking at the full name and then the dollar sign ("\$").

By default, external names can be of any length. IA-64 C++ defaults to **`/NAMES=TRUNCATED`**.

#### **`/[NO]MEMBER_ALIGNMENT`**

`-[no-]member-alignment`

Clang is extended to support the `-[no-]member-alignment` command-line option. It directs the compiler to align the data structure members naturally. This means that the data structure members are aligned on the next boundary appropriate to the type of the member,

rather than on the next byte. For instance, a long variable member is aligned on the next longword boundary; a short variable member is aligned on the next word boundary. Any use of the `#pragma member_alignment` or `#pragma nomember_alignment` directives within the source code overrides the setting established by this qualifier.

Specifying `-no-member-alignment` causes the data structure members to be byte-aligned (with the exception of bit-field members).

#### **/PENDING\_INSTANTIATIONS**

`-ftemplate-depth=n`, sets the maximum instantiation depth for template classes to *n*.

#### **/EXTERN\_MODEL**

The **/EXTERN\_MODEL** qualifier takes the following options (the meaning is the same as for the `#pragma extern_model` directive):

```
COMMON_BLOCK
RELAXED_REFDEF (D)
STRICT_REFDEF= [ "NAME" ]
GLOBALVALUE
```

Clang is extended to support the `-extern-model=option` command-line option. Options are the same as for **CXX**, by default Clang does not set any extern model.

#### **/LIBRARY**

`-text-library=<TEXT_LIBRARY_PATH>`

Clang's option to add text library to include search path.

#### **/LIST**

`-listing-file=<LISTING_FILENAME>`

The Clang option to provide the listing filename. Clang does not add extension by default.

#### **/L\_DOUBLE\_SIZE**

**/L\_DOUBLE\_SIZE=128 (D)**

**/L\_DOUBLE\_SIZE=option**

Determines how the compiler interprets the long double type. The qualifier options are 64 and 128.

**/L\_DOUBLE\_SIZE** for Clang is analogous to `-mlong-double-[128,64,80]`. 80 is supported by Clang, but OpenVMS does not support 80 bit long double size.

#### **/STANDARD**

**/STANDARD=(option)**

**/STANDARD=RELAXED (D)**

The following new keywords are added to explicitly specify C++ standards: CXX98, GNU98, CXX03, GNU03, CXX11, GNU11, CXX14, GNU14.

Example:

- **/STANDARD=CXX03** is translated to `--std=c++03`

- **/STANDARD=GNU03** is translated to `--std=gnu++03`

The value **LATEST** is equivalent to **STRICT\_ANSI**, which is equivalent to **CXX98**. The default standard for **CXX** is set to **GNU98**. The equivalent Clang option is `-std=<value> - language standard to compile for`.

#### **/ARCHITECTURE=option**

Determines the processor instruction set to be used by the compiler. Select one of the **/ARCHITECTURE** qualifier options shown below.

<b>X86=option</b>	Similar to Clang's <code>-march</code> option.  For example:  <code>\$ cxx /arch=x86="skylake" hw.cxx</code>
<b>GENERIC</b>	Ignored.
<b>HOST</b>	Ignored.
<b>ITANIUM2</b>	Ignored.
<b>EV4</b>	Ignored.
<b>EV5</b>	Ignored.
<b>EV56</b>	Ignored.
<b>PCA56</b>	Ignored.
<b>EV6</b>	Ignored.
<b>EV68</b>	Ignored.
<b>EV7</b>	Ignored.

#### **/NESTED\_INCLUDE\_DIRECTORY**

##### **/NESTED\_INCLUDE\_DIRECTORY[=option]**

##### **/NESTED\_INCLUDE\_DIRECTORY=INCLUDE\_FILE (D)**

Controls the first step in the search algorithm the compiler uses when looking for files included using the quoted form of the `#include` preprocessing directive: `#include "file-spec"`. The **/NESTED\_INCLUDE\_DIRECTORY** qualifier has the following options:

<b>Option</b>	<b>Usage</b>
<b>PRIMARY_FILE</b>	Directs the compiler to search the default file type for headers using the context of the primary source file. This means that only the file type (".H" or ".") is used for the default file-spec but, in addition, the chain of "related file-specs" used to maintain the sticky defaults for processing the next top-level source file is applied when searching for the include file. This is not supported for x86-64.
<b>INCLUDE_FILE</b>	Directs the compiler to search the directory containing the file in which the <code>#include</code> directive occurred. The meaning of "directory containing" is: the RMS "resultant string" obtained when the file in which <code>#include</code>

Option	Usage
	<p>occurred was opened, except that the filename and subsequent components are replaced by the default file type for headers (".H", or just "." if <b>/ASSUME=NOHEADER_TYPE_DEFAULT</b> is in effect, <b>/ASSUME</b> is not supported for x86-64).</p> <p>The "resultant string" will not have translated any concealed device logical.</p>
NONE	<p>Directs the compiler to skip the first step of processing <code>#include "file.h"</code> directives. The compiler starts its search for the include file in the <b>/INCLUDE_DIRECTORY</b> directories.</p>

For more information on the search order for included files, see the **/INCLUDE\_DIRECTORY** qualifier.

#### **/FIRST\_INCLUDE**

`-include <file>` – include file before parsing.

#### **/UNDEFINE**

`-U <macro>` – undefine macro `<macro>`.

#### **/LINE\_DIRECTIVES**

`-P` – disable linemarker output in preprocessing mode.

#### **/UNSIGNED\_CHAR**

For the compiler, **/UNSIGNED\_CHAR** is respective to:

- `-fno-signed-char` – char is unsigned.
- `-fsigned-char` – char is signed.

#### **/COMMENTS**

`-C` – includes comments in preprocessed output.

#### **/ERROR\_LIMIT**

**/ERROR\_LIMIT[=*number*]**

#### **/NOERROR\_LIMIT**

Limits the number of error-level diagnostic messages that are acceptable during program compilation. Compilation terminates when the limit (number) is exceeded. **/NOERROR\_LIMIT** specifies that there is no limit on error messages. The default is **/ERROR\_LIMIT=20**, which specifies that compilation terminates after issuing 20 error messages.

`-ferror-limit=n` – stops emitting diagnostics after ***n*** errors have been produced.

#### **/OBJECT**

`-o <file>` – writes output to the file. Default object file has .OBJ extension.



**/PREPROCESS\_ONLY**

-E – only run the preprocessor.

**/RTTI****/RTTI (D)****/NORTTI**

Enables or disables support for RTTI (runtime type identification) features: `dynamic_cast` and `typeid`. Disabling runtime type identification can also save space in your object file because static information to describe polymorphic C++ types is not generated. The default is to enable runtime type information features and generate static information in the object file. The **/RTTI** qualifier defines the macro `__RTTI`. Note that specifying **/NORTTI** does not disable exception handling.

Clang has similar options:

-fno-rtti – disable generation of rtti information.

-frtti – enable generation of rtti information (default).

Clang does not define the `__RTTI` macro.

**/SHOW****/SHOW=(option[,...])****/SHOW=(HEADER,SOURCE) (D)**

Used with the **/LIST** qualifier to set or cancel specific listing options. You can select the following options:

Option	Usage
ALL	Print all listing information.
[NO]HEADER	Print/do not print header lines at the top of each page (D = HEADER)
[NO]INCLUDE	Print/do not print contents of <code>#include</code> files (D = NOINCLUDE)
NONE	Print no listing information
[NO]SOURCE	Print/do not print source file statements (D = SOURCE)
[NO]EXPANSION	Expand preprocessor <code>#if</code> and <code>#elif</code> macros
[NO]STATISTIC	Ignored

Clang's corresponding options are:

- -show-header
- -show-include
- -show-source
- -show-expansion

There are no equivalent -show options that correspond to the **/SHOW=NOHEADER** or **/SHOW=NOSOURCE**. None of these options are enabled by default for Clang.

```
/WARNINGS
/WARNINGS[=(option[,...])]
/WARNINGS (D)
/NOWARNINGS
```

Controls the issuance of compiler diagnostic messages and lets you modify the severity of messages.

The default qualifier, **/WARNINGS**, outputs all enabled warnings. The **/NOWARNINGS** qualifier suppresses warning messages.

The message-list in the following table of options can be any one of the following:

- A single message identifier in double quotes (within parentheses, or not).
- A comma-separated list of message identifiers in double quotes, enclosed in parentheses.
- The keyword "all".

The options are processed and take effect in the following order:

NOWARNINGS	Suppresses warnings. Similar to Clang's <code>-w</code> option.
NOINFORMATIONALS	Has no effect.
ENABLE= <i>message-list</i>	Enables issuance of the specified messages. Can be used to enable specific messages that normally would not be issued when messages disabled with <b>/WARNINGS=DISABLE</b> . Specify <code>all</code> to enable all warnings.
DISABLE= <i>message-list</i>	Similar to Clang's <code>-W&lt;warning&gt;</code> option. Disables issuance of the specified messages. Specify <code>all</code> to suppress all warnings. Similar to Clang's <code>-Wno-&lt;warning&gt;</code> option.
INFORMATIONALS= <i>message- list</i>	Has no effect.
WARNINGS= <i>message-list</i>	Don't error out on the specified warnings. Similar to Clang's <code>-Wno-error=&lt;warning&gt;</code> option.
[NO]ANSI_ERRORS	Has no effect.
[NO]TAGS	Has no effect.
ERRORS= <i>message-list</i>	Sets the severity of the specified messages to Error. Similar to Clang's <code>-Werror=&lt;warning&gt;</code> option.

---

## Important

CXX uses Clang message IDs. For example, if Clang issues a warning such as:

```
warning: non-void function does not return a value [-Wreturn-type]
```

The ID of the message is `return-type`.

All message IDs should be given to CXX as they are in double quotes to preserve the case. This is true for the keyword `all` as well.

There is a list of warnings in Clang that are turned off by default and are enabled with their specific ID or with the keyword `all`. The VMS-specific warning `cast from long pointer to short pointer will lose data` is off by default. It can be enabled with the ID `may-lose-data` or with `all`.

---

#### **/EXCEPTIONS**

`-fexceptions` – enable support for exception handling.

`-fno-exceptions` – disable support for exception handling.

**/OPTIMIZE[=*option*]**

**/OPTIMIZE=(*LEVEL=n*)**

**/NOOPTIMIZE (*D*)**

**LEVEL=*n*** – Selects the level of code optimization. Specify an integer from 0 (no optimization) to 5 (full optimization). Similar to Clang's `-On` option, where  $n = [0, 4]$  and `LEVEL=5` is translated to `-Ofast`.

**[NO]INLINE** – Similar to Clang's `-finline/-fno-inline` options.

#### **Clang's options:**

`-O0, -O1, -O2, -O3, -Ofast, -Os, -Oz, -Og, -O, -O4`

<code>-O0</code>	Means "no optimization": this level compiles the fastest and generates the most debuggable code.
<code>-O1</code>	Somewhere between <code>-O0`</code> and <code>-O2`</code> .
<code>-O2</code>	Moderate level of optimization which enables most optimizations.
<code>-O3</code>	Like <code>-O2`</code> , except that it enables optimizations that take longer to perform or that may generate larger code (in an attempt to make the program run faster).
<code>-Ofast</code>	Enables all the optimizations from <code>-O3`</code> along with other aggressive optimizations that may violate strict compliance with language standards.
<code>-Os</code>	Like <code>-O2`</code> with extra optimizations to reduce code size.
<code>-Oz</code>	Like <code>-Os`</code> (and thus <code>-O2`</code> ), but reduces code size further.
<code>-Og</code>	Like <code>-O1`</code> . In future versions, this option might disable different optimizations in order to improve debuggability.
<code>-O</code>	Equivalent to <code>-O2`</code> .
<code>-O4 and higher</code>	Currently equivalent to <code>-O3`</code>

#### **/VERBOSE**

With this qualifier, the driver first prints out the fully generated command line which is going to Clang, and then runs the compiler.

#### **/PREFIX\_LIBRARY\_ENTRIES**

Only the **/NOPREFIX\_LIBRARY\_ENTRIES** option of this qualifier has an effect. Clang similar option for that option is `-noprefix-lib-entries`. Other options of this qualifier have no effect on OpenVMS x86-64.

## 5.11. Threads and Thread-Local Variables

OpenVMS does not currently support the `thread_local`/`__thread`/`_Thread_local` declaration specifiers provided by the Clang compiler. As an alternative, use the POSIX API functions, such as `pthread_key_create`, `pthread_setspecific`, `pthread_getspecific`, or `pthread_key_delete`.

## 5.12. Online Clang Documentation

The full documentation about the Clang compiler is available at the links below:

<https://releases.llvm.org/10.0.0/tools/clang/docs/index.html>

<https://releases.llvm.org/10.0.0/tools/clang/docs/ClangCommandLineReference.html>

# Chapter 6. Using Templates

A C++ **template** is a framework for defining a set of classes or functions. The process of **instantiation** creates a particular class or function of the set by resolving the C++ template with a group of arguments that are themselves types or values. For example:

```
template <class T> class Array {
    T *data;
    int size;
public:
    T &operator[] (int);
    /* ... */
};
```

The code in this example declares a C++ class template named `Array` that has two data members named `data` and `size` and one subscript operator member function. `Array<int>` instantiates `Array` with type `int`. This instantiation generates the following class definition:

```
class Array {
    int *data;
    int size;
public:
    int &operator[] (int);
    /* ... */
};
```

The compiler supports instantiation of C++ class, function, and static data member templates. On Alpha and IA-64, to understand the differences between the current compiler and Version 5.*n* and to migrate from Version 5.*n* to current compilers, see the appendix on migrating from 5.*n* compilers.

## 6.1. Template Instantiation Model

For every template used in a C++ program, the compiler must create an instantiation for that template. How the compiler does this is referred to as the **template instantiation model**. The template instantiation models differ on the why, what, when, where, and how a template is instantiated. The following outline gives a framework to compare the different models.

### 1. Why

A template can be instantiated **implicitly** when it is used, **manually** by specific request, or both.

### 2. What (part of the template is instantiated)

For a template class, each member of the template can be instantiated separately, or if one member is instantiated then all members are instantiated.

### 3. When

For Alpha and IA-64 systems, instantiation can occur at compile time or link time.

OpenVMS x86-64 C++ supports only compile-time instantiation.

### 4. Where

Templates can be instantiated in the object in which they are referenced or in separate objects that are stored in a repository.

## 5. How

Templates can be instantiated with different linkages. They can be local, global, or **COMDAT** (IA-64 and x86-64 only). A COMDAT is like a weak global definition, but in addition to permitting duplicate definitions, the linker attempts to eliminate all of the duplicates, saving space in the image.

The numbers in the preceding list are used in subsequent paragraphs to indicate which aspect of the template instantiation model framework is being referenced.

For complex systems, choosing a template instantiation model is a space, time, and build-complexity issue that can be considered for optimizing build speed and reducing program size. The default model, referred to as **automatic template instantiation**, is standard-compliant and should work transparently for most users. VSI recommends this model.

Automatic template instantiation:

- Instantiates templates when they are used (1),
- Instantiates only the pieces of a class that are used (2), and
- Occurs at compile time (3).

Template instantiation on Alpha and IA-64 systems differ on the where and the how:

- On Alpha systems, templates are instantiated in a repository (4) using global linkage (5)
- On IA-64 systems, templates are instantiated in the objects that refer to them (4) as COMDATs (5).

On Alpha and IA-64, the compiler, CXXLINK, and linker all work together to assure that all templates used in a program are instantiated and transparently linked into the final image.

On x86-64, the CXX compiler supports the `extern template` feature, which controls explicit instantiation. Declaring an `extern template` prevents implicit instantiation; instead, the compiler relies on an explicit instantiation defined elsewhere. If no such explicit instantiation exists, link errors will occur. For more information, visit [https://en.cppreference.com/w/cpp/language/class\\_template](https://en.cppreference.com/w/cpp/language/class_template).

Even when using automatic template instantiation, manual instantiation (1) is also permitted. When using the default model, manually instantiated templates are placed in the object where the manual instantiation occurs (4). On Alpha systems, they have global linkage; on IA-64 and on x86-64 systems, they are COMDATs (5).

See Table 6.1, "Template Instantiation Models" for a summary of each template instantiation model's What, Where, and How for both implicit and manual instantiation (the "Why").

## 6.2. Manual Template Instantiation

The compiler provides the following methods to instantiate templates manually:

- Using the `#pragma` preprocessor directives. (Alpha and IA-64 only)

Using an instantiation pragma to direct the compiler to instantiate a specific template, as described in Section 6.2.2, "Instantiation Directives (Alpha and IA-64 only)".

- Using explicit template instantiation syntax.

The C++ language now defines specific syntax for specifying that a template should be instantiated.

VSI strongly recommends using the explicit template instantiation syntax when possible.

- Using the command-line qualifier method. (Alpha and IA-64 only)

This method directs the compiler to instantiate templates at compile time in the user's object file. Several qualifiers are available to control linkage and extent of template instantiation. For more information about these qualifiers, see *Section 6.2.3, "Using Command Qualifiers for Manual Instantiation (Alpha and IA-64 only)"*.

## 6.2.1. Mixing Automatic and Manual Instantiation

Object files that have been compiled using manual instantiation can be linked freely with objects that have been compiled using automatic instantiation. To ensure that the template instantiations needed by the files compiled with automatic instantiation are provided, the application must be linked using automatic instantiation, and the appropriate repositories must be present.

When a template instantiation is present in an explicitly named object file or object library it takes precedence over the same named instantiation in a repository.

## 6.2.2. Instantiation Directives (Alpha and IA-64 only)

The next sections describe the following instantiation directives:

```
#pragma define_template
#pragma instantiate_template
#pragma do_not_instantiate_template
```

### 6.2.2.1. #pragma define\_template (Alpha and IA-64 only)

The compiler provides a mechanism for manual instantiation, using the `#pragma define_template` directive. This directive lets you tell the compiler what class or function template to instantiate in conjunction with the actual arguments with which the template is to be instantiated. The `#pragma define_template` directive has the following format:

```
#pragma define_template identifier [<template_arguments>]
```

**Identifier** is the name of the class or function template that the compiler is directed to instantiate at compile time. For the instantiation to succeed, the definition of the template must appear before the `#pragma define_template` directive.

**Template\_arguments** is a list of one or more actual types that correspond to the template parameters for the particular class or function template being instantiated. Whatever type is specified is used as the type for the instantiation.

The following is an example of a valid template manual instantiation:

```
//main.cxx
#include <stdlib.h>
template <class T> void sort (T*);
int a1[100];
float a2[100];
```

```
int main()
{
    sort(a1);
    sort(a2);
    return EXIT_SUCCESS;
}
//sort.cxx
template <class T> void sort (T *array)
{
    /* body of sort */
}
#pragma define_template sort<int>
#pragma define_template sort<float>
```

To compile and link these sources, enter the following command:

```
CXXLINK main.cxx,sort.cxx /TEMPLATE_DEFINE=(NOAUTO)
```

When you use `#pragma define_template` or explicit instantiation, only the specified template is instantiated; templates to which it refers because of member types or base classes are not instantiated.

Sorting an array of template class elements requires the use of additional pragmas for the module `sort.cxx`. For example:

```
template <class T> void sort (T* array)
{
    /*body of sort*/
}
template <class T> class entity {
public:
    T member;
    int operator < (const entity<T> &) const;
}
template <class T>
int entity<T>::operator < (const entity<T> &operand) const
{
    return member < operand.member;
}
int a1[100];
float a2[100];
entity<int> a3[100];
#pragma define_template sort<int>
#pragma define_template sort<float>
#pragma define_template sort<entity<int> >
void sort_all_arrays ()
{
    sort(a1);
    sort(a2);
    sort(a3);
}
```

The `define_template` pragma is position sensitive. If a `define_template` occurs lexically before a function, member function, or static data member template definition, the compiler is unable to instantiate the corresponding template because the body of that template is not present before the pragma directive.

The compiler instantiates all instances of `sort` and of `entity::operator <` needed for this compilation unit.



To organize a program to use the `define_template` pragma, you can place the declarations of class and functions templates into header files, and instantiate all instances of a particular template from a single compilation unit. The following example shows how to do this:

```
// sort.h
#include <stdlib.h>
template <class T> void sort (T*);
// entity.h
template <class T> class entity {
public:
    T member;
    int operator < (const entity<T> &) const;
};
// main.cxx
#include "sort.h"
#include "entity.h"
int a1[100];
float a2[100];
entity<int> a3[100];
int main()
{
    sort(a1);
    sort(a2);
    sort(a3);
    return EXIT_SUCCESS;
}
// sort.cxx
#include "sort.h"
#include "entity.h"
template <class T> void sort (T* array)
{
    /*body of sort*/
}
#pragma define_template sort<int>
#pragma define_template sort<float>
#pragma define_template sort<entity<int> >
```

Compiling the following file provides a definition of `entity::operator <` with type `int`:

```
// entity.cxx
#include "entity.h"
template <class T>
int entity<T>::operator < (const entity<T> &operand) const
{
    return member < operand.member;
}
#pragma define_template entity<int>
```

To compile this example, issue the following command:

```
cxxlink main.cxx,sort.cxx,entity.cxx
```

If the program uses other instantiations of `entity` in other compilation units, you can provide definitions of `operator <` for those entities by adding `define_template` pragmas to `entity.cxx`. For example, if other compilation units use the following instantiations of `entity`, appending the following pragmas to `entity.cxx` causes the compiler to generate instantiations of `operator <` for those requests of `entity`:

```
entity<long> and entity< entity<int> >,
```

```
#pragma define_template entity<long>
#pragma define_template entity< entity<int> >
```

Like any other pragma, the `#pragma define_template` pragma must appear on a single line. Pragas may be continued on multiple lines by escaping the end of line with a backslash ( \ ) as with other preprocessor statements.

### 6.2.2.2. #pragma instantiate and #pragma do\_not\_instantiate (Alpha and IA-64 only)

The compiler also provides several pragmas that provide fine control over the instantiation process. Instantiation pragmas, for example, can be used to control the instantiation of specific template entities or sets of template entities. There are two instantiation pragmas:

- The `instantiate` pragma causes a specified entity to be instantiated, similar to the `define_template` pragma. It provides finer instantiation control than `define_template` when instantiating function templates.
- The `do_not_instantiate` pragma suppresses the instantiation of a specified entity. It is typically used to suppress the instantiation of an entity for which a specific definition is supplied.

The argument to the instantiation pragma can be:

a template class name	<code>A&lt;int&gt;</code>
a template class declaration	<code>class A&lt;int&gt;</code>
a member function name	<code>A&lt;int&gt;::f</code>
a static data member name	<code>A&lt;int&gt;::i</code>
a static data declaration	<code>A&lt;int&gt;::i</code>
a member function declaration	<code>void A&lt;int&gt;::f(int, char)</code>
a template function declaration	<code>char* f(int, float)</code>

A pragma in which the argument is a template class name (for example, `A<int>` or `class A<int>`) is equivalent to repeating the pragma for each member function and static data member declared in the class. When instantiating an entire class, a given member function or static data member may be excluded using the `do_not_instantiate` pragma. For example:

```
#pragma instantiate A<int>
#pragma do_not_instantiate A<int>::f
```

The template definition of a template entity must be present in the compilation for an instantiation to occur. If an instantiation is explicitly requested by use of the `instantiate` pragma and no template definition is available or a specific definition is provided, an error is issued.

```
template <class T> void f1(T); // No body provided
template <class T> void g1(T); // No body provided
void f1(int) {} // Specific definition
#include <stdlib.h>

int main()
{
    int    i;
    double d;
    f1(i);
    f1(d);
}
```

```
    g1(i);
    g1(d);
    return EXIT_SUCCESS;
}
#pragma instantiate void f1(int) // error - specific definition
#pragma instantiate void g1(int) // error - no body provided
```

The functions `f1(double)` and `g1(double)` are not instantiated (because no bodies were supplied) but no errors are produced during the compilation (if no bodies are supplied at link time, a linker error is produced).

A member function name (for example, `A<int>::f`) can be used as a pragma argument only if it refers to a single user-defined member function (that is, not an overloaded function). Compiler-generated functions are not considered, so a name may refer to a user-defined constructor even if a compiler-generated copy constructor of the same name exists. Overloaded member functions can be instantiated by providing the complete member function declaration:

```
#pragma instantiate char* A<int>::f(int, char*)
```

The argument to an instantiation pragma must not be a compiler-generated function, an inline function, or a pure virtual function.

### 6.2.3. Using Command Qualifiers for Manual Instantiation (Alpha and IA-64 only)

Alternatively, you could use the `/TEMPLATE_DEFINE` qualifier to instantiate templates manually.

Considering the previous examples in this section, you can use this qualifier to supply definitions of `sort<int>`, `sort<float>`, and `sort<entity><int>` by compiling the following file using `/TEMPLATE_DEFINE=ALL`:

```
// sort.cxx
#include "sort.h"
#include "entity.h"
template <class T>
static sort (T* array)
{
    /*body of sort*/
}
static void function_never_used ()
{
    int a1[100];
    float a2[100];
    entity<int> a3[100];
    sort(a1);
    sort(a2);
    sort(a3);
}
```

You can use the `/TEMPLATE_DEFINE=USED` and `/TEMPLATE_DEFINE=LOCAL` qualifiers for manual template instantiation. The `/TEMPLATE_DEFINE=USED` qualifier acts like `/TEMPLATE_DEFINE=ALL`, except that only those template instantiations that are referenced in the source file are actually instantiated. The `/TEMPLATE_DEFINE=LOCAL` qualifier acts like `/TEMPLATE_DEFINE=USED`, except that the templates are instantiated with internal linkage. This provides a simple way to build applications but creates executables that are larger than necessary. It also fails if the template classes being instantiated have static data members.

You can use

the `/TEMPLATE_DEFINE=ALL_REPOSITORY`, `/TEMPLATE_DEFINE=USED_REPOSITORY`, and `/TEMPLATE_DEFINE=IMPLICIT_LOCAL` qualifiers to create preinstantiation libraries. See *Section 6.6, "Command-Line Qualifiers for Template Instantiation (Alpha and IA-64 only)"*.

## 6.3. Using Template Object Repositories (Alpha only)

In automatic template instantiation mode, the compiler attempts to instantiate every referenced template at compile time. For automatic instantiation to work, at least one compilation that references a template function must be able to find the template definition. There is no restriction on where a template can be declared or defined, as long as the definition is visible to the compilation unit. You can use implicit inclusion to find it.

The compiler writes instantiation object files to a directory called the repository; file names are based on the names of the entities being instantiated. The default repository is `[.cxx_repository]`.

### 6.3.1. Specifying Alternate Repositories

You can use the `/REPOSITORY` command-line qualifier to specify one or more alternate repository directories. The first repository named is the read-write repository into which the compiler writes instantiation objects when processing. At link time, all repositories are read only. There is one object file in the repository for each instantiated template function, for each instantiated static data member, and for each virtual table required for virtual functions.

When the program is linked, the linker searches the repositories for needed template instantiations.

### 6.3.2. Reducing Compilation Time with the `/TEMPLATE_DEFINE=TIMESTAMP` Qualifier

To keep instantiations up to date, the compiler always instantiates templates by default, even if the required template already exists in the repository. However, in environments that share many templates among many sources, this process can increase compilation time.

In these environments, users can specify the `/TEMPLATE_DEFINE=TIMESTAMP` qualifier to override the default behavior and thereby reduce compilation time. This qualifier causes the compiler to create a timestamp file named `TIMESTAMP .` in the repository. Thereafter, instantiations are added or regenerated only if needed; that is, if they do not already exist, or if existing ones are older than the timestamp.

The `/TEMPLATE_DEFINE=TIMESTAMP` qualifier is immediately useful when building a system from scratch, starting with an empty repository. It avoids reinstantiating unchanged code and is totally safe, because all required instantiations are generated and up to date.

Incremental application building is normally done without this qualifier, so that new instantiations overwrite earlier ones as sources are recompiled.

Although the `/TEMPLATE_DEFINE=TIMESTAMP` qualifier is intended mainly for initial builds, you can use it for ongoing development in a structured way. Because the compiler creates a new timestamp file only if one does not already exist, you must remove or modify any existing timestamp file before making changes to your code base. This procedure ensures that all subsequent compilations generate up-to-date instantiations.

In the following example, the file is removed before and immediately after the compilation of `a.cxx`, `b.cxx`, and `c.cxx`.

```
$ DELETE [.cxx_repository]TIMESTAMP.*
$ CXX /TEMPLATE_DEFINE=TIMESTAMP a.cxx
$ CXX /TEMPLATE_DEFINE=TIMESTAMP b.cxx
$ CXX /TEMPLATE_DEFINE=TIMESTAMP c.cxx
$ DELETE [.cxx_repository]TIMESTAMP.*
```

All instantiations needed by `a.cxx`, `b.cxx`, and `a.cxx` are generated only once, as opposed to the default scheme, in which they would be generated three times if all three modules used the instantiations.

Specifying the `/TEMPLATE_DEFINE=VERBOSE` qualifier causes the compiler to emit an informational message naming the instantiation and repository file being skipped in this mode.

### 6.3.3. Compiling Programs with Automatic Instantiation

In general, the use of automatic template instantiation is transparent to the user. Automatic template instantiation is enabled by default. The following commands are equivalent:

```
CXX file.cxx
CXX/TEMPLATE_DEFINE=(AUTO,PRAGMA) file.cxx
CXX/REPOSITORY=[.CXX_REPOSITORY] file.cxx
```

These commands:

- Cause the compilation of the file `file.cxx`
- Create any instantiations that are required whose definitions are visible to the compiler
- Create an executable, `a.out`, by linking together the generated object file and any instantiations required from the repository

You can specify the repository explicitly with the `/REPOSITORY` qualifier. For example:

```
CXX /REPOSITORY=C$:[PROJECT.REPOSITORY] file.cxx
```

This command compiles `file.cxx`, produces an object file in the current directory, and puts instantiated template files in the directory `C$:[PROJECT.REPOSITORY]`.

You can specify multiple directories using the `/REPOSITORY` qualifier. The first named repository is denoted as the read/write repository. The compiler writes instantiation files to this repository. The other repositories are denoted as read only repositories. They are searched by the link command as described in *Section 6.3.4, "Linking Programs with Automatic Instantiation"*.

The compiler attempts to instantiate templates at compile time; therefore, any specialization used in the program must be declared in each file in which the specialization is referenced, to prevent the instantiation of the overridden template function.

If a template instantiation refers to a static function, that function is created as an external entry point in the primary object file, and the instantiation object file in the repository then refers to this `__STF` function.

If the template instantiation is linked into an application that does not have the original primary object file, an unresolved reference to the `__STF` function occurs. If this happens, recompile an object file that regenerates the instantiation or use manual instantiation to reinstantiate the template.

## 6.3.4. Linking Programs with Automatic Instantiation

When compiling and linking an application, you must use the same repositories in both the compilation and link steps.

If you name a repository explicitly in the compile step, you must also name it in the link step. For example:

```
CXX /REPOSITORY=[.MY_REPOSITORY] a.cxx,b.cxx
CXXLINK /REPOSITORY=[.MY_REPOSITORY] a.obj b.obj
```

If you use different repositories the compilation of the sources, you must specify all of them on the link step:

```
CXX /REPOSITORY=[.REPOSITORY1] a.cxx
CXX /REPOSITORY=[.REPOSITORY2] b.cxx
CXXLINK /REPOSITORY=( [.REPOSITORY1],[.REPOSITORY2]) a.obj b.obj
```

At link time, the specified repositories are searched in the order given, to find the required instantiations. If you use several repositories, and if one of them is the default, you must specify all repositories on the link step:

```
CXX a.cxx
CXX /REPOSITORY=[.REPOSITORY2] b.cxx
CXX /REPOSITORY=( [.CXX_REPOSITORY],[.REPOSITORY2]) a.obj b.obj
```

It is usually much easier and safer to use a single repository, because the same instantiations could potentially be present in multiple repositories, and it is possible to update some but not all repositories when changes are made to templates.

The CXXLINK step processes object files so that all the external symbol references are resolved. The objects are linked together in the following order:

1. The order in which object files and object libraries are specified on the command line.
2. If /NOTEMPLATE\_PRELINK is specified, stop.
3. For each unresolved external, search the repositories in the order specified on the command line for an file that contains that external. If such a file is found, add it at the top of the list of object files being searched.
4. Link again and repeat Step 3 until no more externals are found or until no more object files are found in which to resolve the external.

Note the following:

- Instantiations that appear in explicitly linked object files or libraries hide instantiations in the repositories.
- Only template instantiations that are actually referenced in sources that can instantiate them appear in the repository. You must specify any other instantiations manually or use the /TEMPLATE\_DEFINE=ALL\_REPOSITORY qualifier.
- Instantiations are satisfied from the list of unsatisfied externals from the linking of specified files, but are linked at the beginning of those files. This means that they are linked in only if they are satisfied from no specified file, given the linker's file order behavior, and if they bring in any external references they need from the first library that satisfies them.

### 6.3.5. Creating Libraries

Creating libraries with object files created with automatic instantiations is relatively straightforward. You must decide where the instantiations that were generated automatically are provided to the users of the library. For applications that use the library to link successfully, all template instantiations that are needed by the code in the library must be available at link time. This can be done in two ways:

- Put the instantiations in the library. They hide the same named instantiations in any repositories or any libraries following the library on the command line.
- Provide a repository that contains the instantiations.

It is usually easiest to put the instantiations in the library. This is a good choice if the instantiations are internal to the library and are not instantiated directly by the user's code. To put the instantiations in the library, add all of the object files in the repositories required by the library into the library as shown in the following example:

```
CXX /REPOSITORY=[.lib_repository] a.cxx,b.cxx,c.cxx
LIBRARY/CREATE/OBJECT mylib
LIBRARY/INSERT/OBJECT mylib a.obj,b.obj,c.obj
LIBRARY/INSERT/OBJECT mylib [.lib_repository]*.OBJ
```

If the template instantiations can be overridden by the user, the templates should be provided in a repository that the user specifies after all the user's repositories. For the previous example, create the library as follows:

```
CXX /REPOSITORY=[.lib_repository] a.cxx,b.cxx,c.cxx
LIBRARY/CREATE/OBJECT mylib
LIBRARY/INSERT/OBJECT mylib a.obj,b.obj,c.obj
```

When linking the application, enter the CXXLINK command as follows:

```
CXXLINK user_code.obj,mylib/LIB
```

If some objects from [.lib\_repository] are not contained in mylib.olb, specify [.lib\_repository] as the last read-only repository on the line follows:

```
CXXLINK /REPOSITORY=( [.cxx_repository], [.lib_repository])
        user_code.obj,mylib/LIB
```

You must explicitly name the repository when linking, even if it is the default repository [.cxx\_repository]; cxx first satisfies all unresolved instantiations from [.cxx\_repository], and uses [.lib\_repository] to resolve any remaining unresolved instantiations.

Only the instantiations that are required by the code in the library are generated in the library repository lib\_repository. If you must provide other instantiations that you require but cannot instantiate, you must provide these instantiations using manual template instantiation or by specifying the qualifier / TEMPLATE\_DEFINE=ALL\_REPOSITORY.

### 6.3.6. Multiple Repositories

As shown in Section 6.5.3, "Creating a Common Instantiation Library (Alpha and IA-64 only)", multiple repositories can be specified to link an application. The first repository named is the read-write repository, and when compiling, the compiler writes instantiation object files into it. At link time, all repositories are read only.

The repositories are searched in a linear order, iteratively, and satisfy only the unresolved instantiations from each pass. That is, references from instantiations that are added in one pass are not resolved until the next pass. Consider the link line in the previous example:

```
mylib.o lb
```

In this example, all references that could be resolved from `lib_repository` would be resolved in the first pass. Any reference arising from an instantiation in `lib_repository` in the first pass would be resolved by instantiations in `[.cxx_repository]` in the second pass.

## 6.4. Using COMDATS (IA-64 and x86-64 only)

The primary purpose of a template repository is to guarantee that only one copy of a template instantiation is included in a program. Another way to achieve this is to use COMDATs. COMDATs are special symbols that are globally visible; however, when the linker encounters a duplicate definition, it is removed. This allows the compiler to define templates directly in every object module that uses them.

The principal benefit of using COMDATS is build speed, but it also can simplify the build procedure:

- Compilation speed is improved because writing template instantiations into the current object is significantly faster than writing them into the repository, because of object overhead in the latter case.
- Link speed is improved because determining which templates to include from the template repository requires multiple passes of the linker.
- The build is simplified by eliminating the need to manage the template repository and explicitly extract objects.

COMDATs are implemented on IA-64 and x86-64 systems using ELF group sections. COMDATs are not implemented on Alpha systems because EOBJ does not support them. If EOBJ supported COMDATs, then they also would have been used on Alpha systems instead of the template object repository. Currently, there are no plans to implement COMDATs on Alpha systems.

Because templates instantiated using COMDATs exist in the same object where they are used, there are no special procedures for linking programs or creating libraries, except that a template can only be exported from a single shared library. If two shared libraries with the same exported template are linked together, a MULDEF will occur. This restriction also exists on Alpha systems.

## 6.5. Advanced Program Development and Templates

The following sections discuss templates in the context of advanced program development.

### 6.5.1. Implicit Inclusion (Alpha and IA-64 only)

When implicit inclusion is enabled, the compiler assumes that if it needs a definition to instantiate a template entity declared in a `.h` or `.hxx` file, it can implicitly include the corresponding implementation file to obtain the source code for the definition.

If a template entity `ABC::f` is declared in file `xyz.h`, and an instantiation of `ABC::f` is required in a compilation but no definition of `ABC::f` appears in the source code, the compiler checks whether a file `xyz.cxx` exists. If it does, the compiler processes it as if it were included at the end of the main source file.



When looking for a template definition, the compiler uses the following lookup order:

1. If the `#include` name for the header file containing the template declaration is specified with an absolute path name, look only in the directory specified by the path name.
2. If the `#include` for the header file containing the template declaration is specified with a relative path name, take the following action:
  - If the header file name is specified with double quotation marks (" ") and the `/NOCURRENT_INCLUDE` qualifier was not specified, append the relative path name to the directory containing the source file and search for files with the appropriate suffixes.
  - Otherwise, append the relative path name to all the `-I` directories and look in those resulting directories for files with the appropriate suffixes.

---

## Note

A place containing a forward slash (/) character is considered to be a UNIX-style name. If the name in the `#include` directive also contains a "/" character that is not the first character and is not preceded by an exclamation mark character (!) (that is, it is not an absolute UNIX-style pathname), the name in the `#include` directive is appended to the named place, separated by a "/" character, before applying the `decc$to_vms` pathname translation function.

---

For source files, the appropriate suffixes are, in order of preference: `.CXX`, `.C`, `.CC`, and `.CPP` or as defined by the `/TEMPLATE_DEFINE=DEFINITION_FILE_TYPE` qualifier.

The compiler ignores any file extension that does not begin with a dot (.).

The `/TEMPLATE_DEFINE=DEFINITION_FILE_TYPE` qualifier allows the user to define explicitly the file extensions to be used with implicit inclusion. For example:

```
CXX file.cxx /TEMPLATE_DEFINE=DEF=".CPP.CC"
```

This command searches for template definition files with the extensions `.CPP` and `.CC`.

## 6.5.2. Dependency Management (Alpha and IA-64 only)

The compiler does no dependency management of its own. Because template instantiations are compiled when source files that reference those instantiations are compiled, those source files must be recompiled if the template declaration or definition changes.

The `/MMS` output from the compiler lists the implicitly included files, so that the MMS program can automatically recompile any source files that depend upon template files. If MMS is not being used, it is the user's responsibility to ensure that instantiations that have changed are recompiled. The user does so by recompiling at least one source file that references the changed instantiations.

The compiler does not check command line dependencies of template instantiations at link time. If you compile two different source files that instantiate a specific template with two different sets of qualifiers, the behavior is undefined. Use consistent qualifier settings for each build into each repository. Examples of qualifier settings that could cause unexpected results are as follows:

- `/STANDARD=STRICT_ANSI`. Use of guiding declarations is not allowed, and some templates might not be instantiated as they would be in other modes.

- `/DEBUG`. Debug information is generated for some instantiations and not for others. Be sure that is what you want.
- `/NOMEMBER_ALIGNMENT`. Some instantiations with this setting assume that classes have unaligned members; instantiations generated by compiling files with the default setting do not.

### 6.5.3. Creating a Common Instantiation Library (Alpha and IA-64 only)

Because the automatic instantiation model has changed to a compile time model with Version 6.0, (see *Section 6.3.3, "Compiling Programs with Automatic Instantiation"* and *Section 6.3.4, "Linking Programs with Automatic Instantiation"*), the procedure used to create a common instantiation library has also changed. This section describes the new procedure.

If you want to put all current instantiations into a common instantiation library, follow these steps:

1. Compile with the `/TEMPLATE=VERBOSE` qualifier and save the results to a file.
2. Edit that file and save the names that appear after the “automatically instantiating ...” string. You can ignore any messages about instantiating vttables. Put `#pragma instantiate` before each name.
3. Put the result of that edit into a separate source file and include at the top of the file any headers needed for template definitions.
4. Put matching `#pragma do_not_instantiate` (see *Section 6.2.2.2, "#pragma instantiate and #pragma do\_not\_instantiate (Alpha and IA-64 only)"*) into the headers that define each of these template classes or functions.
5. Place each `#pragma do_not_instantiate` directive between an `#ifndef` of the form `#ifndef SOME_MACRO_NAME` and an `#endif`.
6. Compile the `inst.cxx` file with `SOME_MACRO_NAME` defined.
7. Link the source file with the resulting object file.

The following examples show how to create a common instantiation library for all the instantiations currently being automatically instantiated for this file.

```
// foo.cxx
#include <stdlib.h>
#include <vector>
#include "C.h"
int main() {
    vector<C> v;
    v.resize(20);
    return EXIT_SUCCESS;
}
// C.h
#ifndef __C_H
class C {};
#endif
```

Compiling with the `/TEMPLATE=VERBOSE` qualifier shows which instantiations occur automatically:

1. Place all these instantiations into a file called `inst.cxx` that is built separately or into a library:

```
// inst.cxx
```

```
#include <vector>
#include "C.h"
#pragma instantiate void std::vector<C, std::allocator<C >
>::resize(unsigned long)
#pragma instantiate void std::vector<C, std::allocator<C >
>::insert(C *, unsigned long, const C &)
#pragma instantiate void std::vector<C, std::allocator<C >
>::__insert(C *, unsigned long, const C &, __true_category)
#pragma instantiate C *std::copy_backward(C *, C *, C *)
#pragma instantiate void std::fill(C *, C *, const C &)
#pragma instantiate C *std::copy(C *, C *, C *)
#pragma instantiate const unsigned long std::basic_string<char,
std::char_traits<char >, std::allocator<void> >::npos
```

2. Add these instantiations into `C.h` and change “instantiate” to “do\_not\_instantiate”. Add an `#ifndef`, so that when building `inst.cxx`, the compiler creates these instantiations in the `inst` object file:

```
#ifndef __C_H
class C {};
#endif
#pragma do_not_instantiate void std::vector<C, std::allocator<C >
>::resize(unsigned long)
#pragma do_not_instantiate void std::vector<C, std::allocator<C >
>::insert(C *, unsigned long, const C &)
#pragma do_not_instantiate void std::vector<C, std::allocator<C >
>::__insert(C *, unsigned long, const C &, __true_category)
#pragma do_not_instantiate C *std::copy_backward(C *, C *, C *)
#pragma do_not_instantiate void std::fill(C *, C *, const C &)
#pragma do_not_instantiate C *std::copy(C *, C *, C *)
#pragma do_not_instantiate const unsigned long
std::basic_string<char, std::char_traits<char >,
std::allocator<void> >::npos
#endif
```

3. Build the `inst` object file:

```
CXX/DEFINE=BUILDING_INSTANTIATIONS inst.cxx
```

4. Link with the `inst` object file. It will use instantiations from that file instead of creating them automatically:

```
cxx foo.cxx
cxxlink foo inst
```

To verify that your procedure worked correctly, you can remove all files from the `cxx_repository` subdirectory before you compile `foo.cxx`. This subdirectory should contain no instantiations after linking with the `inst` object file.

If you have an `inst.cxx` file that contains many instantiations and you do not want all the symbols in the `inst` object file to be put into a user's executable even if only some symbols are used, (as happens with archive libraries), you can either split the `inst.cxx` into many smaller source files, or specify the `/DEFINE_TEMPLATE=USED_REPOSITORY` qualifier to create the instantiations as separate object files in the repository (see *Section 6.6, "Command-Line Qualifiers for Template Instantiation (Alpha and IA-64 only)"*). You must then link all the required individual object files in the repository into your library.

## 6.6. Command-Line Qualifiers for Template Instantiation (Alpha and IA-64 only)

This section describes the C++ command-line qualifiers that specify the template instantiation model, and additional template-related qualifiers.

### 6.6.1. Instantiation Model Qualifiers

The following CXX command-line qualifiers specify the template instantiation model to be used. Specify only one:

#### **`/TEMPLATE_DEFINE=ALL`**

Instantiate all template entities declared or referenced in the compilation unit, including typedefs. For each fully instantiated template class, all its member functions and static data members are instantiated even if they were not used. Nonmember template functions are instantiated even if the only reference was a declaration. Instantiations are created with external linkage. Overrides `/REPOSITORY` at compile time. Instantiations are placed in the user's object file.

#### **`/TEMPLATE_DEFINE=ALL_REPOSITORY`**

Instantiate all templates declared or used in the source program and put the object code generated as separate object files in the repository. Instantiations caused by manual instantiation directives are also put in the repository. This is similar to `/TEMPLATE_DEFINE=ALL` except that explicit instantiations are also put in the repository, rather than than an external symbol being put in the main object file. This qualifier is useful for creating a pre-instantiation library.

#### **`/TEMPLATE_DEFINE=[NO]AUTOMATIC`**

`/TEMPLATE_DEFINE=AUTOMATIC` directs the compiler to use the automatic instantiation model of C++ templates.

`/TEMPLATE_DEFINE=NOAUTOMATIC` directs the compiler to not implicitly instantiate templates.

`/TEMPLATE_DEFINE=AUTOMATIC` is the default.

#### **`/TEMPLATE_DEFINE=IMPLICIT_LOCAL`**

Same as `/TEMPLATE_DEFINE=LOCAL`, except manually instantiated templates are placed in the repository with external linkage. This is useful for build systems that need to have explicit control of the template instantiation mechanism. This mode can suffer the same limitations as `/TEMPLATE_DEFINE=LOCAL`. This mode is the default when `/STANDARD=GNU` is specified.

#### **`/TEMPLATE_DEFINE=LOCAL`**

Similar to `/TEMPLATE_DEFINE=USED` except that the functions are given internal linkage. This qualifier provides a simple mechanism for getting started with templates. The compiler instantiates as local functions the functions used in each compilation unit, and the program links and runs correctly (barring problems resulting from multiple copies of local static variables). However, because many copies of the instantiated functions can be generated, this qualifier might not be suitable for production use.

The `/TEMPLATE_DEFINE=LOCAL` qualifier cannot be used in conjunction with automatic template instantiation. If automatic instantiation is enabled by default, it is disabled by the `/TEMPLATE_DEFINE=LOCAL` qualifier. Explicit use of `/TEMPLATE_DEFINE=LOCAL` and `/TEMPLATE_DEFINE=AUTO` is an error.

### **`/TEMPLATE_DEFINE=USED`**

Instantiate those template entities that were used in the compilation. This includes all static data members for which there are template definitions. Overrides `/TEMPLATE_DEFINE=AUTO` at compile time.

### **`/TEMPLATE_DEFINE=USED_REPOSITORY`**

Like `/TEMPLATE_DEFINE=ALL_REPOSITORY`, but instantiates only templates used by the compilation. The explicit instantiations are also put into the repository as separate object files.

Table 6.1, "*Template Instantiation Models*" summarizes each template instantiation model's What, Where, and How (as described in Section 6.1, "*Template Instantiation Model*") for both implicit and manual instantiation.

**Table 6.1. Template Instantiation Models**

<b>Model (/TEMPLATE=)</b>	<b>Why Implicit</b>			<b>Why Manual</b>		
	<b>What</b>	<b>Where</b>	<b>How</b>	<b>What</b>	<b>Where</b>	<b>How</b>
AUTO	part	repository for Alpha, object for IA-64	global for Alpha, COMDAT for IA-64	part	object	global for Alpha, COMDAT for IA-64
NOAUTO	N/A	N/A	N/A	part	object	global for Alpha, COMDAT for IA-64
IMPLICIT_LOCAL	part	object	local for Alpha, COMDAT for IA-64	part	object	global for Alpha, COMDAT for IA-64
LOCAL	part	object	local for Alpha, COMDAT for IA-64	part	object	local for Alpha, COMDAT for IA-64
USED	part	object	global for Alpha, COMDAT for IA-64	part	object	global for Alpha, COMDAT for IA-64
USED_REPO	part	repository	global for Alpha, COMDAT for IA-64	part	repository	global for Alpha, COMDAT for IA-64
ALL	all	object	global for Alpha, COMDAT for IA-64	all	object	global for Alpha, COMDAT for IA-64

Model (/TEMPLATE=)	Why Implicit			Why Manual		
	What	Where	How	What	Where	How
ALL_REPO	all	repository for Alpha, object for IA-64	global for Alpha, COMDAT for IA-64	all	repository for Alpha, object for IA-64	global for Alpha, COMDAT for IA-64

## 6.6.2. Other Instantiation Qualifiers

The following qualifiers are independent of the model used and each other:

### **/TEMPLATE\_DEFINE=DEFINITION\_FILE\_TYPE="file-type-list"**

Specifies a string that contains a list of file types that are valid for template definition files. Items in the list must be separated by commas and preceded by a period. A type is not allowed to exceed the OpenVMS limit of 31 characters. This qualifier is applicable only when automatic instantiation has been specified. The default is `/TEMPLATE_DEFINE=DEF=".CXX,.C,.CC,.CPP"`.

### **/TEMPLATE\_DEFINE=PRAGMA**

Determines whether the compiler ignores `#pragma define_template` directives encountered during the compilation. This qualifier lets you quickly switch to automatic instantiation without having to remove all the pragma directives from your program's code base. The default is `/TEMPLATE_DEFINE=PRAGMA`, which enables `#pragma define_template`.

### **/TEMPLATE\_DEFINE=VERBOSE**

Turns on verbose or verify mode to display each phase of instantiation as it occurs. During the compilation phase, informational level diagnostics are generated to indicate which templates are automatically being instantiated. This qualifier is useful as a debugging aid.

### **/PENDING\_INSTANTIATIONS[=n]**

Limit the depth of recursive instantiations so that infinite instantiation loops can be detected before some resource is exhausted. The `/PENDING_INSTANTIATIONS` qualifier requires a positive non-zero value `n` as argument and issues an error when `n` instantiations are pending for the same class template. The default value for `n` is 64.

## 6.6.3. Repository Qualifiers

The following qualifiers are only applicable if a repository is being used (*Alpha only*):

### **/TEMPLATE\_DEFINE=TIMESTAMP**

Causes the compiler to create a timestamp file named `TIMESTAMP .` in the repository. Thereafter, instantiations are added or regenerated only if needed; that is, if they do not already exist, or if existing ones are older than the timestamp.

### **/REPOSITORY**

Specifies a repository that C++ uses to store requested template instantiations. The default is `/REPOSITORY=[.CXX_REPOSITORY]`. If multiple repositories are specified, only the first is considered writable, and the default repository is ignored unless specified.

# Chapter 7. Handling C++ Exceptions

Exception handling is a C++ language mechanism for handling unusual program events (not just errors).

This includes support for throwing and catching exceptions, and calling the `terminate()` and `unexpected()` functions. C++ exception-handling support is implemented using functions and related OpenVMS system services that comprise the OpenVMS condition-handling facility. Hence, C++ exception-handling support is fully integrated with existing uses of the OpenVMS condition handling facility.

## 7.1. Compiling with Exceptions

Because exceptions are enabled by default, you need not specify the `/EXCEPTIONS` qualifier whenever you compile the program.

For more information about the `/EXCEPTIONS` qualifier see *Appendix A, "Compiler Command Qualifiers"*.

---

### Note

If you are programming in kernel mode or creating a protected shareable image, C++ exception handling is not supported. To ensure that your code does not contain constructs that trigger C++ exceptions or to prevent errors from occurring during initialization of exception handlers at runtime, specify the `/NOEXCEPTIONS` qualifier when compiling.

---

## 7.2. Linking with Exceptions (Alpha only)

If any files in your program contain throw expressions, try blocks, or catch statements, or if any files in your program are compiled with the exceptions, you must link your program using the `cxlink` facility (see *Section 1.3, "Linking a Program (Alpha only)"* for more information on this facility). For example:

```
$ cxlink my_prog.obj
```

Using the `cxlink` facility ensures that the run-time support for exceptions (`sys$library:libcxxstd.olb`) is linked into your program.

### Linking with `/NOSYSSHR` (OpenVMS Version 6.2)

If you want to link using the `/NOSYSSHR` qualifier, you must specify a linker options file on your `cxlink` command. Otherwise, your link might fail because of undefined symbol references.

The linker options file should contain the following:

```
sys$share:librtl.exe/shar
```

For example, if `cx_exc.opt` is your linker options file containing the above line, then a possible link command would be:

```
$ cxlink my_prog.obj, my_disk:[my_dir]cx_exc.opt/opt
```

For more information about linking with /NOSYSSHR and about OpenVMS linker options files see the *VSI OpenVMS Linker Utility Manual*.

## 7.3. The `terminate()` and `unexpected()` Functions

On Alpha and IA-64 systems, the `unexpected()` and `set_unexpected()` functions are implemented as defined in the appropriate C++ language standard.

On x86-64 systems, by default, the `terminate()` function doesn't raise the OpenVMS condition `cxxl$terminate`, it only calls `default_terminate_handler`, which calls the `abort()` function.

On Alpha systems, no stack unwinding is done by the `terminate()` function. Hence, no destructors are called for constructed objects when a thrown exception results in a call of the `terminate()` function. Instead, the program is terminated.

On IA-64 and x86-64 systems, stack unwinding *is* done.

If a C++ function is called from a program in which the main function is not C++, `terminate()` is not called. Instead, the call stack points to the point of the throw.

## 7.4. C++ Exceptions and Other Conditions

Because C++ exceptions are implemented using the OpenVMS condition handling facility, C++ modules will work properly when they are part of a program that makes other uses of OpenVMS condition handling.

The raising and handling of an OpenVMS condition can result in the destruction of C++ automatic objects. If the handling of an OpenVMS condition results in an unwind through a C++ function's stack frame, then destructors will be called for automatic objects declared in that stack frame, just as if a C++ exception had been caught by a handler in an outer stack frame.

The C++ exception handling facility can also be used to catch OpenVMS conditions that are raised independently of C++ throw expressions. Except for those OpenVMS conditions that result in the delivery of signals, a C++ `catch(...)` handler will catch both C++ thrown exceptions and OpenVMS conditions. (For more information about OpenVMS conditions that result in the delivery of signals, see *Section 7.5, "C++ Exceptions and Signals (Alpha only)"*.)

### Alpha and IA-64 only

You can use the data type `struct chf$signal_array &`, defined in the system header file `chfdef.h`, to catch OpenVMS conditions and to obtain information about the raised conditions. The C++ exceptions support transfers control to `catch(struct chf$signal_array &)` handlers when it determines that an OpenVMS condition was raised independently of a C++ throw statement.

If the `catch (struct chf$signal_array &)` handler specifies a class object, then the C++ exceptions support sets the class object to be a reference to the raised OpenVMS condition's signal argument vector. In the following example, `obj.chf$l_sig_name` will have the value 1022 when it is printed:

```
#include <chfdef.h>
#include <iostream.hxx>
#include <lib$routines.h>
```



```
main ()
{
    try {
        lib$signal (1022);
    } catch (struct chf$signal_array &obj) {
        cout << obj.chf$l_sig_name << endl;
    }
}
```

A `catch(struct chf$signal_array &)` handler will also catch a thrown object that is explicitly declared to be of type `struct chf$signal_array &`. In this case, the value of the catch handler's object is determined by the originally thrown object, not the OpenVMS signal argument vector.

You can also use the data type `struct chf$signal_array *` to catch both OpenVMS conditions and objects explicitly declared to be of type `struct chf$signal_array *`. If a `catch(struct chf$signal_array *)` handler specifies an object, then that object becomes a pointer to the thrown object.

#### **x86-64 only**

You can use the data type **`struct chf64$signal_array *`**, defined in the system header file **`chfdef.h`**, to catch the OpenVMS conditions and to obtain information about the raised conditions. The C++ exceptions support transfers control to **`catch(struct chf64$signal_array *)`** handlers when it determines that an OpenVMS condition was raised independently of a C++ throw statement. Also, you need to define the **`__NEW_STARLET`**.

Example:

```
#define __NEW_STARLET 1
#include <chfdef.h>
#include <iostream>
#include <lib$routines.h>

int main ()
{
    try {
        lib$signal (1022);
    } catch (struct chf64$signal_array * obj) {
        std::cout << obj->chf64$q_sig_name << std::endl;
    }
}
```

For more information about OpenVMS conditions, see the OpenVMS Calling Standard.

## **7.5. C++ Exceptions and Signals (Alpha only)**

Certain OpenVMS conditions (as described in the [VSI C Run-Time Library Reference Manual for OpenVMS Systems](https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/) [https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/]) normally result in the delivery of signals. These signals can be processed using the signal handler mechanism described in the [VSI C Run-Time Library Reference Manual for OpenVMS Systems](https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/) [https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/].

You can call the following run-time function in conjunction with the `/EXCEPTION=IMPLICIT` qualifier to cause these OpenVMS conditions to be treated as exceptions, instead of signals:

```
cxxl$set_condition(condition_behavior signal_or_exc)
```

This can be done by putting the following call in your program:

```
#include <cxx_exception.h>
...
cxxl$set_condition (cxx_exception);
```

---

## Caution

You must specify `/EXCEPTION=IMPLICIT`; otherwise, the code that would normally cause a signal and now causes an exception might be moved out of the try block.

---

After your program calls the `cxxl$set_condition (cxx_exception)` function you can then catch these exceptions using any of the following handlers:

```
catch(struct chf$signal_array &)
catch(struct chf$signal_array *)
catch(...)
```

To revert back to the default signal behavior, you can make the following call:

```
cxxl$set_condition (unix_signal);
```

---

## Caution

Avoid doing a C++ throw from a C signal handler or OpenVMS exception handler because this action could terminate your program.

---

The following are defined in the header file `cxx_exception.h`:

The `cxxl$set_condition()` function

The `condition_behavior {unix_signal=0, cxx_exception=1}` enumeration type

The `cxxl$set_condition` function returns the previous setting. This function affects all threads in a process.

## 7.6. C++ Exceptions with `setjmp` and `longjmp`

### Alpha and IA-64 only

If a C++ function calls either the `setjmp()` or the `longjmp()` routine, C++ exceptions support is disabled for that function. This means the following:

- No exceptions can be caught by the function's catch handlers.
- No destructors are called for the function's automatic data if an exception propagates through the function.
- The `unexpected()` function is not called for that function.
- If either `setjmp()` or `longjmp()` is called from `main()`, then `terminate()` is not called for an unhandled exception.

### x86-64 only

The C++ standard specifies that the interaction between C++ exceptions and `set jmp/long jmp` functions leads to undefined behavior if replacing `set jmp` and `long jmp` with `catch` and `throw` would result in the invocation of non-trivial destructors for any automatic objects.

## 7.7. C++ Exceptions, `lib$establish` and `vaxc$establish`<sup>1</sup>

If a C++ function calls either the `lib$establish()` or the `vaxc$establish()` routine, then C++ exceptions support is disabled for that function. This means the following:

- No exceptions can be caught by the function's catch handlers.
- No destructors are called for the function's automatic data if an exception propagates through the function.
- The `unexpected()` function is not called for that function.
- If either `lib$establish()` or `vaxc$establish()` is called from `main()`, then `terminate()` is not called for an unhandled exception.

## 7.8. Performance Considerations

The compiler optimizes the implementation of exception handling for normal execution, as follows:

- Applications that do not use C++ exceptions and are compiled with the `/NOEXCEPTIONS` qualifier incur no run-time or image size overhead.
- Applications compiled with exceptions enabled that have try blocks or automatic objects with destructors incur an increase in image size.
- As much as possible, the run-time overhead for exceptions is incurred when throwing and catching exceptions, not when entering and exiting try blocks normally.

## 7.9. C++ Exceptions and Threads

C++ exceptions are thread safe. This means that multiple threads within a process can throw and catch exceptions concurrently. However, exceptions do not propagate from one thread to another, nor can one thread catch an exception thrown by another thread.

The `set_terminate()` and `set_unexpected()` functions set the `terminate()` and `unexpected()` handlers for the calling thread. Therefore, each thread in a program has its own `terminate()` and `unexpected()` handlers.

If you want every thread in your program to use the same nondefault `terminate()` or `unexpected()` handlers, then you must call the `set_terminate()` and `set_unexpected()` functions separately from each thread.

### Alpha and IA-64 only

By default, the C++ exception package allows the delivery of the `CMA$_EXIT_THREAD` condition, but not the `CMA$_ALERTED` condition. This latter condition is raised to a thread that is being

---

<sup>1</sup>`vaxc$establish` is not supported on x86-64 CXX system.

cancelled. The following routine (`test_thread`) allows an application to control the default behavior of these two conditions:

```
int cxxl$catchable_condition (int condition, int on_or_off);
```

The condition is either `CMA$_EXIT_THREAD` or `CMA$_ALERTED`. A value of zero means the program does not want the condition to result in a catch clause receiving the exception. This is the default behavior for `CMA$_ALERTED`. A value of nonzero means the program does want the condition to result in the catch clause of the thread to receive control when the exception is raised. The behavior is undefined for any other condition value passed.

The return value of the routine is the previous setting for the passed condition value:

```
#include <pthread.h>
#include <cxx_exception.h>
#include <cma$def.h>
...
static void *test_thread (...) {
    ...
    try {
        ...
    } catch (chf$signal_array *p) {
        switch (p->chf$l_sig_name) {
            case CMA$_ALERTED:
                printf (" test_thread caught CMA$_ALERTED\n");
                break;
            default:
                printf (" test_thread caught (%d)\n", p->chf$l_sig_name);
                break;
        }
    }
}
int main () {
    ...
    if (cxxl$catchable_condition(CMA$_ALERTED,1))
        printf (" CMA$_ALERTED continues to be catchable\n");
    else printf (" CMA$_ALERTED is now catchable\n");
    ...
    pthread_create (&thread, ...);
    ...
    pthread_cancel (thread);
    ...
}
```

For more information about threads, see the *Guide to POSIX Threads Library* manual.

## 7.10. Debugging with C++ Exceptions (Alpha only)

You can use the OpenVMS Debugger **set break/exception** command to set a breakpoint when an exception is thrown. You can use the **show calls** command to determine the location where the exception was thrown.

# Chapter 8. The C++ Standard Library

The C++ Standard Library provided with this release defines a complete specification of the C++ International Standard, with some differences, as described in the online release notes in: `SYS$HELP:CXX_RELEASE_NOTES.PS`

Note that portions of the C++ Standard Library have been implemented in VSI C++ using source licensed from and copyrighted by Rogue Wave Software, Inc. Information pertaining to the C++ Standard Library has been edited and incorporated into VSI C++ documentation with permission of Rogue Wave Software, Inc. All rights reserved.

Some of the components in the C++ Standard Library are designed to replace nonstandard components that are currently distributed in the Class Library. VSI will continue to provide the Class Library in its nonstandard form. However, you now have the option of using new standard components.

This chapter provides more information on the VSI C++ implementation of the Standard Library, including upward compatibility, compiling, linking, and thread safety. Small example programs showing how to use the C++ standard library are located in the directory `SYS$COMMON:[SYSHLP.EXAMPLES.CXX]`<sup>1</sup>.

The following are Standard Library qualifiers introduced with VSI C++:

## **/[NO]USING\_STD (IA-64 and Alpha only)**

Controls whether standard library header files are processed as though the compiled code were written as follows:

```
using namespace std;
#include <header>
```

These qualifiers are provided for compatibility for users who do not want to qualify use of each standard library name with `std::` or put `using namespace std;` at the top of their sources.

`/USING_STD` turns implicit using namespace std on; this is the default when compiling `/STANDARD=ARM`, `/STANDARD=MS`, or `/STANDARD=RELAXED`.

`/NOUSING_STD` turns implicit using namespace std off; this is the default when compiling `/STANDARD=STRICT_ANSI`.

## **/ASSUME=[NO]STDNEW (IA-64 and Alpha only)**

Controls whether calls are generated to the ANSI or pre-ANSI implementation of the operator `new()`. On memory allocation failure, the ANSI implementation throws `std::bad_alloc`, while the pre-ANSI implementation returns 0.

`/ASSUME=STDNEW` generates calls to the ANSI `new()` implementation; this is the default when compiling with `/STANDARD=RELAXED` and `/STANDARD=STRICT_ANSI`.

`/ASSUME=NOSTDNEW` generates calls to the pre-ANSI `new()` implementation; this is the default when compiling with `/STANDARD=ARM` and `/STANDARD=MS`.

---

<sup>1</sup>The mentioned directory is supported on Alpha and IA-64 only.

**/ASSUME=[NO]GLOBAL\_ARRAY\_NEW (IA-64 and Alpha only)**

Controls whether calls to global array new and delete are generated as specified by ANSI. Pre-ANSI global array new generated calls to `operator new()`. According to ANSI, use of global array new generate calls to `operator new() []`.

`/ASSUME=GLOBAL_ARRAY_NEW` generates calls to `operator new() []` for global array new expressions such as `new int[4]`; this is the default when compiling `/STANDARD=RELAXED`, `/STANDARD=STRICT_ANSI`, and `/STANDARD=MS`.

`/ASSUME=NOGLOBAL_ARRAY_NEW` generates calls to `operator new()` for global array new expressions such as `new int[4]` and preserves compatibility with Version 5.n; this is the default when compiling `/STANDARD=ARM`.

## 8.1. Important Compatibility Information

On Alpha systems, the standard library is distributed as system shareable images `SYS$LIBRARY:LIBCXXSTD.EXE` and `SYS$LIBRARY:CXXL$011_SHR.EXE`, and also in object form in `SYS$LIBRARY:LIBCXXSTD.OLB`.

On IA-64 systems, the standard library is distributed as a system shareable image `SYS$LIBRARY:CXXL$RWRTL.EXE`, and also in object form in the system object library `STARLET.OLB`.

On x86-64 systems, there is only one C++ Standard Library, hence there is no need for the `/[NO]USING_STD` qualifier. The standard library is distributed as a system shareable image `SYS$LIBRARY:LIBCXX.EXE`, and also in object form `SYS$LIBRARY:LIBCXX.OLB`.

The `__USE_STD_Iostream` and `__NO_USE_STD_Iostream` macros are not defined and defining them has no effect.

The following sections describe specific compatibility issues where the x86-64 C++ Standard Library emulates ANSI behavior.

### 8.1.1. `/[NO]USING_STD` Compiler Compatibility Qualifier (IA-64 and Alpha only)

All standard library names in VSI C++ are inside the namespace `std`. Typically you would qualify each standard library name with `std::` or put `using namespace std;` at the top of your source file.

To make things easier for existing users, `using namespace std;` is included in a file provided with every standard library header when you are in ARM, MS, or RELAXED compiler modes. This is not the default in STRICT\_ANSI mode.

The compiler supplied qualifiers `/NOUSING_STD` and `/USING_STD` can be used to override the default. `/NOUSING_STD` turns the implicit using namespace `std` off; `/USING_STD` turns it on.

### 8.1.2. Pre-ANSI/ANSI Iostreams Compatibility

The C++ Standard Library offers support for the standard iostream library based on the C++ International Standard. As defined by the standard, iostream classes are in the new header files `<iostream>`, `<ostream>`, `<istream>`, and so on (no `.h` or `.hxx` extension).

**Alpha and IA-64 only**

For backward compatibility, the pre-ANSI iostream library is still provided. The two libraries exhibit subtle differences and incompatibilities.

Users can choose which version (ANSI or pre-ANSI) of iostreams they want to use; either version of iostreams can be integrated seamlessly with the new Standard Library and string functionality.

To accomplish this goal, macros called `__USE_STD_Iostream` and `__NO_USE_STD_Iostream` are provided. If you do not set these macros explicitly, the default in ARM, MS, and RELAXED modes is to use the pre-ANSI iostream library. In `STRICT_ANSI` mode, the default is to use the ANSI iostream library.

Note that for the most part, support for pre-ANSI iostreams is contained in headers with `.h` or `.hxx` extensions. This is not the case for `iostream.h/iostream.hxx`, `fstream.h/fstream.hxx`, and `iomanip.h/iomanip.hxx`. In these cases, the iostream library provided is controlled solely by the `/STANDARD` compilation choice and use of `__USE_STD_Iostream/`  
`__NO_USE_STD_Iostream`.

You override the default by defining `__USE_STD_Iostream` or `__NO_USE_STD_Iostream` on either the command line or in your source code.

In ARM, MS, and RELAXED modes, specify use of the ANSI iostreams in one of the following ways:

- Enter `/DEFINE=(__USE_STD_Iostream)` on the command line.
- Put the following in your source file before any include files:

```
#ifndef __USE_STD_Iostream
#define __USE_STD_Iostream
#endif
```

In `STRICT_ANSI` mode, specify use of the pre-ANSI iostreams in one of the following ways:

- Enter `/DEFINE=(__NO__USE_STD_Iostream)` on the command line.
- Put the following in your source file before any include files:

```
#ifndef __NO_USE_STD_Iostream
#define __NO_USE_STD_Iostream
#endif
```

You receive a `#error` warning if

- you compile in a mode indicating you want ANSI behavior; that is, `/STANDARD=STRICT_ANSI`,
- you enter a header with a `.h` or `.hxx` (for example, `#include <iostream.h>`).

You can avoid the error by compiling with `/DEFINE=(__NO_USE_STD_Iostream)`.

Many of the other headers, `<string>` for example, make use of the iostream classes. The default version of iostreams that is automatically included when you include one of these headers depends on the mode you compile in and the setting of the macros `__USE_STD_Iostream` and `__NO_USE_STD_Iostream` as described earlier.

Because the standard locale class and the standard iostream class are so closely tied, you cannot use the standard locale class with the pre-ANSI iostream classes. If you want to use locale, you must use the ANSI iostream classes.

It is possible to use the pre-ANSI and the ANSI iostream library in the same source file, because all the standard iostream names (that is, `cout`, `cin`, and so on) are in namespace `std`, and all the pre-ANSI names are in the global namespace. This is not recommended, though, because there is no guarantee of stream objects being the same size or, for example, of `::cout` being in sync with `std::cout`.

Nevertheless, if you want to combine them, you must recognize that the underlying ANSI iostream is called `iostream_stdimpl.hxx` and that the pre-ANSI header is called `iostream_impl.hxx`. The following example shows how to include a pre-ANSI header before and ANSI header:

```
#include <stdlib.h>
#undef __USE_STD_IOSTREAM
#include <iostream_impl.hxx>
#define __USE_STD_IOSTREAM
#include <iostream_stdimpl.hxx>

int main()
{
    std::string s("abc");
    ::cout << "abc" << endl;           // pre-standard iostreams
    std::cout << "abc" << std::endl;    // standard iostreams
    return EXIT_SUCCESS;
}
```

If you include an ANSI iostreams header before a pre-ANSI iostreams header, follow these steps:

1. Compile your source using `/NOUSING_STD`.
2. Use the `__USE_STD_IOSTREAM` macro as shown in the following example. You must define `__USE_STD_IOSTREAM` at the end of your include file list so that the template definition files (the `.cc` files) are included in the correct mode.

```
// Compile this with /nousing_std
#include <stdlib.h>
#define __USE_STD_IOSTREAM
#include <iostream_stdimpl.hxx>
#undef __USE_STD_IOSTREAM
#include <iostream_impl.hxx>
#define __USE_STD_IOSTREAM // so the template definition files are ok

int main()
{
    std::string s("abc");
    ::cout << "abc" << endl; // pre-standard iostreams
    std::cout << "abc" << std::endl; // standard iostreams
    return EXIT_SUCCESS;
}
```

### 8.1.3. Support for pre-ANSI and ANSI operator `new()`

---

#### Warning

VSI OpenVMS x86-64 supports only the ANSI operator `new()`.

---



The Standard C++ Library supports the ANSI implementation of the `operator new()` as well as the pre-ANSI implementation of `operator new()`. The ANSI implementation throws `std::bad_alloc` on memory allocation failures.

The pre-ANSI implementation of the `operator new()` returns 0 on memory allocation failures. Because the ANSI behavior is incompatible with pre-ANSI applications, a compile time qualifier has been added (`/ASSUME=[NO]STDNEW`) to control whether calls to ANSI `new()` or pre-ANSI `new` are generated.

The following examples show how ANSI versus pre-ANSI `new()` check for memory allocation. First, here is an ANSI `new()` check for memory allocation failure:

```
try {
    myobjptr = new (myobjptr);
}
catch (std::bad_alloc e) {
    cout << e.what() << endl;
};
```

The following example shows a pre-ANSI `new()` check for memory allocation failure:

```
if ((myobjptr = new (myobjptr)) == 0)
    call_failure_routine();
```

When upgrading pre-ANSI `new()` code to work with the C++ Standard Library you also can use the `nothrow` version of ANSI `new()`. To do so in the pre-ANSI example, you could recode it as follows:

```
if ((myobjptr = new (myobjptr, nothrow)) == 0)
    call_failure_routine();
```

On Alpha and IA-64 systems, two command line qualifiers are available in the compiler to control whether calls are generated to the ANSI or pre-ANSI implementation of `operator new()`:

- Use the `/ASSUME=STDNEW` qualifier to generate calls to the ANSI `new()` implementation.
- Use the `/ASSUME=NOSTDNEW` qualifier to generate calls to the pre-ANSI `new()` implementation. You can override global `new()` by declaring your own functions.

When compiling with `/STANDARD=RELAXED` or `/STANDARD=STRICT_ANSI`, `/ASSUME=STDNEW` is the default.

When compiling with `/STANDARD=ARM` and `/STANDARD=MS`, `/ASSUME=NOSTDNEW` is the default. The compiler defines the macro `__STDNEW` when the `/ASSUME=STDNEW` qualifier is specified.

### 8.1.4. Overriding operator new() (Alpha only)

On Alpha systems, the ability to override the library version of global `operator new()` and global `operator delete()` is available. If you want to define your own version of global `operator new()` on OpenVMS systems, you must define your own version of global `operator delete()` and vice versa. To define a global `operator new()` or a global `operator delete()` to replace the version used by the C++ Standard Library or the C++ Class Library, or both, follow these steps:

1. Define a module to contain two entry points for your version of global `operator new()`. You must code the module so that it is always compiled either with the `/ASSUME=STDNEW` or with the `/ASSUME=NOSTDNEW` qualifier.

2. If you code your module to compile with `/ASSUME=STDNEW`, follow instructions in the next subsection. If you code your module to compile with `/ASSUME=NOSTDNEW`, follow instructions in the section called “*Compiling with /ASSUME=NOSTDNEW*”.

## Compiling with `/ASSUME=STDNEW`

1. Verify that your module contains two entry points for your version of global operator `new()`. One entry point, which has the name `__nw__XUi` (`/MODEL=ARM`) or `__7__nw__FUi` (`/MODEL=ANSI`), is used to override global operator `new()` in the Class Library. The other entry point, which has the name `new`, is used to override global operator `new()` in the Standard Library.
2. Define global operator `new()` in terms of the entry point `new`. Code `__nw__XUi` (for `/MODEL=ARM`) or `__7__nw__FUi` (for `/MODEL=ANSI`) to call operator `new`. Your module appears as follows:

```
#include <new>
...
using namespace std;

// Redefine global operator new(),
// entry point into C++ Standard Library based on
// compiling /assume=stdnew. This also overrides user
// calls to operator new().
void *operator new(size_t size) throw(std::bad_alloc) {
    printf("in my global new\n");
    ...
    void *p = malloc(size);
    return(p);
}

// redefine global operator delete()
void operator delete(void *ptr) throw() {
    free(ptr);
}

// entry point into C++ Class Library
#ifdef __MODEL_ANSI
extern "C" void *__7__nw__FUi(size_t size) {
#else // __MODEL_ARM
extern "C" void *__nw__XUi(size_t size) {
#endif
    printf("in my new\n");
    return ::operator new(size);
}
```

## Compiling with `/ASSUME=NOSTDNEW`

1. Verify that your module contains two entry points for your version of global operator `new()`. One entry point, which has the name `cxx1$__stdnw__XUi` (for `/MODEL=ARM`) or `cxx1$__7__stdnw__FUi` (for `/MODEL=ANSI`), is used to override global operator `new()` in the Standard Library. The other entry point, which has the name `new`, is used to override global operator `new()` in the Class Library.
2. Define global operator `new()` in terms of the entry point `new`. Code `cxx1$__stdnw__XUi` (`/MODEL=ARM`) or `cxx1$__stdnw__FUi` (`/MODEL=ANSI`) to call operator `new`. Your module appears as follows:

```
#include <new>
...
using namespace std;

// Redefine global operator new(),
// entry point into C++ Class Library based on
// compiling /assume=nostdnew
void *operator new(size_t size) {
    printf("in my global new\n");
    ...
    void *p = malloc(size);
    return(p);
}

// redefine global operator delete()
void operator delete(void *ptr) {
    free (ptr);
}

// entry point into C++ Standard Library
#ifdef __MODEL_ANSI
extern "C" void *cxxl$__7__stdnw__FUi(size_t size) {
#else // __MODEL_ARM
extern "C" void *cxxl$__stdnw__XUi(size_t size) {
    return ::operator new(size);
}
}
```

3. Link your program using the /NOSYSSHR qualifier of the LINK command. You must also link with a linker options file that includes the shareable images your program requires. (This is because some components of OpenVMS systems ship only in shareable form.) The file contains at least the shareable images shown below. The options file cannot contain, DECC\$SHR, because it contains the definitions of new() and delete() that you are attempting to override. So your LINK command will be similar to the following:

```
$ CXXLINK TEST, SYS$LIBRARY:STARLET.OLB/INCLUDE=CXXL_INIT, -
SYS$DISK:[ ]AVMS_NOSYSSHR.OPT/OPT/NOSYSSHR
```

where AVMS\_NOSYSSHR.OPT is:

```
SYS$SHARE:CMA$TIS_SHR/SHARE
SYS$SHARE:LIBRTL/SHARE
```

Linking /NOSYSSHR is the only way to override calls to new() and delete() in the C++ Class Library and C++ Standard Library.

If the set\_new\_handler() function is referenced when overriding operator new() and delete(), “multiply defined” linker warnings will result. To remove these warnings, the set\_new\_handler() function must also be overridden. Using set\_new\_handler() when the operator new() and delete() functions are being overridden, requires that the set\_new\_handler() function be defined in terms of the user provided operator new() and delete() functions.

### 8.1.5. Overriding operator new() (IA-64 only)

Overriding operators new and delete has been simplified on IA-64 systems. If user code overrides any of the new and delete operators, the compiler and library picks up the overridden versions

without any other changes to the source code or the command line. Changes such as those described for Alpha systems in *Section 8.1.4, "Overriding operator new() (Alpha only)"* are unnecessary and will not work on IA-64 systems.

### 8.1.6. Overriding operator new() (x86-64 only)

On x86-64 systems if user code overrides any of the class-specific new and delete operators, the compiler and library pick up the overridden versions without any other changes to the source code or the command line.

However, global new and delete operator overrides are currently not supported on x86-64 systems, which is a known issue.

### 8.1.7. IOStreams Expects Default Floating-Point Format

The C++ standard library IOStreams expects floating-point values in the default floating-point format for each platform: G\_FLOAT on Alpha systems and IEEE on IA-64 and x86-64 systems. Using standard library IOStreams for processing floating-point values in a different format (for example, in a program compiled /FLOAT=IEEE on Alpha or /FLOAT=G\_FLOAT on IA-64 and x86-64) is not supported. The C++ class library does not have this restriction.

## 8.2. How to Build Programs Using the C++ Standard Library

Building programs that use the C++ Standard Library requires the following changes in usage of the C++ compiler and linker commands:

- The CXX command line no longer needs to include the /ASSUME=NOHEADER\_TYPE\_DEFAULT qualifier because this is now the default.

Similarly, the command line no longer needs to include the /TEMPLATE=AUTO qualifier because the compiler performs automatic template instantiation by default.

- On Alpha systems, to link a program that uses the C++ Standard Library, you must use the CXXLINK command in place of the LINK command. The CXXLINK command continues the automatic template instantiation process, includes the Standard Library run-time support (SYSS\$LIBRARY:LIBCXXSTD.OLB) at link time, and creates the final image. See *Section 1.3, "Linking a Program (Alpha only)"* for more details. (Alpha only)
- On IA-64 systems, to link a program that uses the C++ Standard Library, you must use either the CXXLINK facility or OpenVMS Linker. See *Section 1.4, "Linking a Program (IA-64 only)"* for more details. (IA-64 only)

For example, to build a program called `prog.cxx` that uses the Standard Library, you can use the following commands:

```
$ CXX prog.cxx
$ CXXLINK prog.obj
```

- On x86-64 systems, to link a program that uses the C++ Standard Library, you must use the OpenVMS Linker. See *Section 1.5, "Linking a Program (x86-64 only)"* for more details. (x86-64 only)

## Thread Safety

The Standard Library provided with this release is thread safe but not thread reentrant. Thread safe means that all library internal and global data is protected from simultaneous access by multiple threads. In this way, internal buffers as well as global data like `cin` and `cout` are protected during each individual library operation. Users, however, are responsible for protecting their own objects.

According to the C++ standard, results of recursive initialization are undefined. To guarantee thread safety, the compiler inserts code to implement a spinlock if another thread is initializing local static data. If recursive initialization occurs, the code deadlocks even if threads are not used.

## 8.3. Optional Switch to Control Buffering (Alpha only)

The `inplace_merge`, `stable_sort`, and `stable_partition` algorithms require the use of a temporary buffer. Two methods are available for allocating this buffer:

- Preallocate 16K bytes of space on the stack.
- Allocate the required amount of storage dynamically.

By default, the current VSI C++ Standard Library makes use of the preallocated buffer, which avoids the overhead of run-time allocation. If your application requires a buffer that exceeds 16K, it cannot take advantage of this default.

If you are concerned with minimizing the use of stack space in your program, or if your application requires a buffer that exceeds 16K, define the `__DEC_DYN_ALLOC` macro to enable dynamic buffering. Do this by adding the following to your compile command line:

```
/DEFINE=__DEC_DYN_ALLOC
```

## 8.4. Enhanced Compile-time Performance of ANSI Iostreams

To speed the compile-time performance of programs that use the standard `iostream` and `locale` components, the Standard Library includes many common template instantiations of these components.

To force programs to create instantiations at compile-time (for example, if you want to debug them and thus need them to be compiled with the `/DEBUG` qualifier), define the macro `__FORCE_INSTANTIATIONS` (*Alpha only*) on the command line by specifying `/DEFINE=(__FORCE_INSTANTIATIONS)`. This definition suppresses the `#pragma do_not_instantiate` directives in the headers so that the compiler creates the instantiations in your repository directory.

You must then specify the `/REPOSITORY=` qualifier to force the compiler to link your instantiations instead of those in the Standard Library.

## 8.5. Using RMS Attributes with Iostreams

The standard library class `fstream` constructors and `open()` member function do not support different RMS attributes, for example, creating a stream-lf file.

To work around this restriction, use the C library `creat()` or `open()` call, which returns a file descriptor, and then use the `fstream` constructor, which accepts a file descriptor as its argument. For example:

```
#define __USE_STD_IOSTREAM
#include <fstream>

int main()
{
    int fp;

    // use either creat or open
    //if ( !(fp = creat("output_file.test", 0, "rfm=stmlf")) )

    if ( !(fp = open("output_file.test", O_WRONLY | O_CREAT | O_TRUNC , 0,
"rfm=stmlf")) )
        perror("open");

    ofstream output_file(fp); // use special constructor, which takes
                             // a file descriptor as argument

    // ...
}
```

Note that this coding is not allowed if you compile with `/STANDARD=STRICT_ANSI`, because the constructor in the example is an extension to the C++ standard interface.

## 8.6. Upgrading from the Class Library to the Standard Library (Alpha and IA-64 only)

The following discussion guides you through upgrading the Class Library code to use the Standard Library, specifically replacing the vector and stack classes in the `vector.hxx` header file to the Standard Library vector and stack classes.

### 8.6.1. Upgrading from the Class Library Vector to the Standard Library Vector

To change your code from using the Class Library vector to the Standard Library vector, consider the following actions:

- Change the name of your `#include` statement from `<vector.h>` or `<vector.hxx>` to `<vector>`.
- Remove the `vectordeclare` and `vectorimplement` declarations from your code.
- Change all `vector(type)` declarations to `vector<type>`. For example, `vector(int) vi` should become `vector<int> vi`.
- The following member functions are replaced in the Standard Library:

Nonstandard Vector Function	Standard Library Vector Function
<code>elem(int index)</code>	<code>operator[](size_t index)</code> (no bounds checking)

Nonstandard Vector Function	Standard Library Vector Function
<code>operator[](int index)</code>	<code>at(size_t index)</code> (bounds checking)
<code>setsize(int newsize)</code>	<code>resize(size_t newsize)</code>

- When copying vectors of unequal lengths, note that the Standard Library vector has a different behavior as follows:

When using the Standard Library vector, if the target vector is smaller than the source vector, the target vector automatically increases to accommodate the additional elements.

The Class Library vector displays an error and aborts when this situation occurs.

- Note that another difference in behavior occurs when you specify a negative index for a vector.

The Class Library vector class detects the negative specification and issues an error message. However, the Standard Library vector silently converts the negative value to a large positive value, because indices are represented as type `size_t` (unsigned `int`) rather than `int`.

- When an out-of-bounds error occurs, the Class Library vector prints an error message and aborts, whereas the Standard Library vector throws an out-of-range object.

## 8.6.2. Upgrading from the Class Library Stack to the Standard Library Stack

To change your code from using the existing stack to the Standard Library stack, consider the following actions:

- Change the name of your `#include` statement from `<stack.h>` or `<stack.hxx>` to `<stack>`.
- Remove the `stackdeclare` and `stackimplement` declarations from your code.
- Change all `stack(type)` declarations to `stack<type, deque<type> >`. For example, `stack(int) si` should become `stack<int, deque<int> > si`.
- Do not specify an initial size for a Standard Library stack. The stack must start out empty and grow dynamically (as you push and pop).
- The following member functions are not supported or have different semantics:

Class Library Stack	Standard Library Stack
<code>size_used()</code>	Does not exist because the <code>size()</code> function always is equal to the <code>size_used()</code> function.
<code>full()</code>	Does not exist because the stack always is full.
<code>pop()</code>	Does not return the popped element. To simulate Class Library behavior, first obtain the element as the return type from the <code>top()</code> function and then call the <code>pop()</code> function. For example, change <code>int i=s.pop();</code> to the following:  <code>int i=s.top();</code>

Class Library Stack	Standard Library Stack
	<code>s.pop();</code>

- The Standard Library stack differs from the Class Library stack in the way errors are detected. Unlike the nonstandard stack, you cannot overflow a Standard Library stack because space is allocated dynamically as you push elements onto the stack.

### 8.6.3. Upgrading from the Class Library String Package Code

The Standard Library `basic_string` can replace the Class Library String Package.

The following list guides you through upgrading nonstandard code to use the Standard Library `basic_string`:

- Change `#include <string.h>` or `#include <string.hxx>` to `#include <string>`.
- Change all declarations of `String` to `string` (uppercase S to lowercase s).
- On Alpha systems, when compiling with the `__DEC_STRING_COMPATIBILITY` macro defined, the String Package allowed assignment of a string directly to a `char *`; however, the `basic_string` library does not allow this. You can assign the string's `const char *` representation using the `c_str()` or `data()` `basic_string` member functions. For example:

```
string s("abc");
char* cp = s; // not allowed
const char* cp = s.data(); // ok
```

The state of the string is undefined if the result of `data()` is cast to a non-`const char *` and then the value of that `char *` is changed.

- The String Package member functions `upper()` and `lower()` are not in the `basic_string` library. You can write these functions as nonmember functions, as follows:

```
template <class charT, class traits, class Allocator>
inline
basic_string<charT, traits, Allocator>
upper(const basic_string<charT, traits, Allocator>& str) {
    basic_string<charT, traits, Allocator> newstr(str);
    for (size_t index = 0; index < str.length(); index++)
        if (islower(str[index]))
            newstr[index] = toupper(str[index]);
    return newstr;
}

template <class charT, class traits, class Allocator>
inline
basic_string<charT, traits, Allocator>
lower(const basic_string<charT, traits, Allocator>& str) {
    basic_string<charT, traits, Allocator> newstr(str);
    for (size_t index = 0; index < str.length(); index++)
        if (isupper(str[index]))
            newstr[index] = tolower(str[index]);
}
```



```
        return newstr;
    }
```

Then instead of calling `upper()` and `lower()` as member functions of the `basic_string`, pass the string as an argument. For example:

```
s2 = s1.upper(); // does not compile
s2 = upper(s1); // ok
```

- The String Package `match()` member function does not exist. Equivalent functionality exists in the Standard Library algorithm `mismatch()`, although using it is more complicated. For example:

```
string s1("abcdef");
string s2("abcdgf");
assert(s1.match(s2)==4); // does not compile
pair<string::iterator,string::iterator> p(0,0); // ok
p=mismatch(s1.begin(),s1.end(),s2.begin());
assert(p.first-s1.begin()==4);
string s3 = s1;
p=mismatch(s1.begin(),s1.end(),s3.begin());
assert(p.first == s1.end()); // everything matched
```

- The String Package `index()` member function does not exist. The `basic_string` library equivalent is `find()`.
- The String Package constructor that takes two positional parameters (a start and end position) and constructs a new string does not exist. It is replaced in the `basic_string` library with the member function `substr()`. For example:

```
string s1("abcde");
string s2 = s1(1,3); // does not compile
string s2 = s1.substr(1,3); // ok
```

- Many previously undetected run-time errors now throw standard exceptions in the String library.

## 8.6.4. Upgrading from the Class Library Complex to the ANSI Complex Class

---

### Note

On IA-64 systems, the Class Library Complex package has been removed, so upgrading to the Standard Library complex class is the only option on this platform. (*IA-64 only*)

---

This section explains how to upgrade from the pre-ANSI complex library to the current standard complex library.

In the pre-ANSI library, complex objects are not templatized. In the ANSI library, complex objects are templatized on the type of the real and imaginary parts. The pre-ANSI library assumes the type is double, whereas the ANSI library provides specializations for float, double, and long double as well as allowing users to specialize on their own floating point types.

Mathematical error checking is not supported in the ANSI library. Users who rely on detection of underflow, overflow, and divide by zero should continue using the pre-ANSI complex library.

The following is a detailed list of important changes:

- Change `#include <complex.h>` or `#include <complex.hxx>` to `#include <complex>`.

- Change all declarations of `complex` to `complex<double>`, for example:

```
complex c;
```

Change to:

```
complex<double> c;
```

- The `polar()` function no longer supplies a default value of 0 for the second argument. Users will have to explicitly add it to any calls that have only one argument, for example:

```
complex c;  
c = polar(c); // get polar
```

Change to:

```
complex<double> c;  
c = polar(c, 0.0);
```

- If you are calling a mathematical function or mathematical operator that takes scalars as arguments (`polar()` for example), then you must adjust the arguments you pass in to be the same type as the complex template parameter type. For example, you would have to change:

```
complex c = polar(0, 0);  
complex c2 = c + 1;
```

Change to:

```
complex<double> c = polar(0.0, 0.0); // 0.0 is double  
complex<double> c2 = c + 1.0; // 1.0 is double
```

- The `complex_zero` variable is not declared in the complex header file. If you want to use it, you will have to declare it yourself. For example, add the following to the top of your source file:

```
static const complex<double> complex_zero(0.0, 0.0);
```

- The `sqr()` and `arg1()` functions are gone. If you want to continue to use them, you should define them in one of your own headers, using the following definitions:

```
template <class T>  
inline complex<T> sqr(const complex<T>& a)  
{  
    T r_val(real(a));  
    T i_val(imag(a));  
    return complex<T>  
        (r_val * r_val -  
         i_val * i_val,  
         2 * r_val * -i_val);  
}
```

```
template <class T>  
inline T arg1(const complex<T>& a)  
{  
    T val = arg(a);
```

```
if(val > -M_PI && val <= M_PI)
    return val;

if(val > M_PI)
    return val - (2*M_PI);

// val <= -PI
return val + (2*M_PI);
}
```

- The `pow(complex, int)` function is no longer provided. You must use `pow(complex<double>, double)`. This means changing calls such as:

```
pow(c, 1);
```

Change to:

```
pow(c, 1.0);
```

This might yield different results. If the function previously was underflowing or overflowing, it might not continue to happen.

- The complex output operator (`<<`) does not insert a space between the comma and the imaginary part. If you want the space, you would need to print the real and imaginary parts separately, adding your own comma and space; that is:

```
complex<double> c;
cout << "(" << c.real() << ", " << c.imag() << ")"; // add extra space
```

- The complex input operator (`>>`) does not raise an `Objection` if bad input is detected; it instead sets input stream's state to `ios::failbit`.
- Floating point overflow, underflow, and divide by zero do not set `errno` and will cause undefined behavior. Complex error checking and error notification is planned for a subsequent release.
- You should no longer need to link your program explicitly with the complex library. It is automatically linked in as part of the Standard Library. However, you must still explicitly link in the C math library, as shown in the following example:

```
#include <stdlib.h>
#include <complex>

int main() {
    complex<double> c1(1,1), c2(3.14,3.14);
    cout << "c2/c1: " << c2/c1 << endl;
    return EXIT_SUCCESS;
    % cxx example.cxx #error
    % cxx example.cxx -lm #okay
}
```

### 8.6.5. Upgrading from the Pre-ANSI iostream library to the VSI C++ Standard Library

This section explains how to upgrade from the pre-ANSI iostream library to the ANSI iostream library. In this section, pre-ANSI iostreams refers to versions of the iostream library found in the Class Library; ANSI iostreams refers to versions found in the VSI C++ Standard Library.

There are a number of differences between the pre-ANSI and ANSI iostream library. One major difference between the pre-ANSI and ANSI iostream library is that the ANSI library is templized on the object input/output on which operations are being performed. In the pre-ANSI library, iostreams has no templates. The ANSI library also provides specializations for `char` and `wchar_t`.

Important differences are as follows:

- With the current compiler, you access the pre-ANSI iostream library by default in non `strict_ansi` compiler modes. You can control the version of iostreams you use with the `__USE_STD_Iostream` and `__NO_USE_STD_Iostream` macros. If you want to use the ANSI iostream library, do either of the following:

- Enter `/DEFINE=__USE_STD_Iostream` on the command line.
- Put the following in your source file before any include files:

```
#ifndef __USE_STD_Iostream
#define __USE_STD_Iostream
#endif
```

- Header names are different in the ANSI library, so to use ANSI iostreams, change the iostreams headers you include as follows:

From	To
<code>#include &lt;iostream.h&gt;</code>	<code>#include &lt;iostream&gt;</code>
<code>#include &lt;iostream.hxx&gt;</code>	
<code>#include &lt;fstream.h&gt;</code>	<code>#include &lt;fstream&gt;</code>
<code>#include &lt;fstream.hxx&gt;</code>	
<code>#include &lt;strstream.h&gt;</code>	<code>#include &lt;strstream&gt;</code>
<code>#include &lt;strstream.hxx&gt;</code>	
<code>#include &lt;iomanip.h&gt;</code>	<code>#include &lt;iomanip&gt;</code>
<code>#include &lt;iomanip.hxx&gt;</code>	

- All Standard Library names in the ANSI iostream library are in namespace `std`. Typically you would qualify each Standard Library name with `std::` or put `using namespace std;` at the top of your source file.

On Alpha and IA-64 systems, to facilitate upgrading in all but `STRICT_ANSI` mode, `using namespace std;` is set by default. In `STRICT_ANSI` mode, after including an ANSI iostream header, you must qualify each name inside namespace `std` individually or do

```
using namespace std;
```

- In the pre-ANSI iostream library, including `<iomanip.h>` or `<strstream.h>` gave you access to `cout`, `cin`, and `cerr`. To access the predefined streams with the ANSI iostream library, make the following changes:

change	change
<code>#include &lt;iomanip.h&gt;</code>	<code>#include &lt;strstream.h&gt;</code>

to	to
<code>#include &lt;iomanip&gt;</code>	<code>#include &lt;stringstream&gt;</code>
<code>#include &lt;iostream&gt;</code>	<code>#include &lt;iostream&gt;</code>
<code>#include using namespace std;</code>	<code>using namespace std;</code>

- The `istream::ipfx`, `istream::isfx`, `ostream::opfx`, `ostream::osfx` do not exist in the ANSI iostreams. Their functionality is provided by the sentry class found in `basic_istream` and `basic_ostream`, respectively.

Common prefix code is provided by the sentry's constructor. Common suffix code is provided by the sentry's destructor. As a result, calls to `ipfx()`, `isfx()`, `opfx()`, and `osfx()` have their functionality replaced by construction and destruction of `std::istream::sentry` objects and `std::ostream::sentry` object respectively. For example:

<code>#include &lt;iostream.hxx&gt;</code>	<code>#include &lt;iostream.hxx&gt;</code>
<code>void func (istream &amp;is)</code>	<code>void func (ostream &amp;os)</code>
<code>{</code>	<code>{</code>
<code>if (is.ipfx())</code>	<code>if (os.opfx())</code>
<code>...</code>	<code>...</code>
<code>is.isfx();</code>	<code>os.osfx();</code>
<code>}</code>	<code>}</code>
Would be coded as:	Would be coded as:
<code>#include &lt;iostream&gt;</code>	<code>#include &lt;iostream&gt;</code>
<code>void func (istream &amp;is)</code>	<code>void func (ostream &amp;os)</code>
<code>{</code>	<code>{</code>
<code>istream::sentry ipfx(is);</code>	<code>ostream::sentry opfx(os);</code>
<code>if (ipfx)</code>	<code>if (opfx)</code>
<code>...</code>	<code>...</code>
<code>//is.isfx(); implicit in dtor</code>	<code>//os.osfx(); implicit in dtor</code>
<code>}</code>	<code>}</code>

- The following macros from the pre-ANSI `<iomanip.h>` are no longer available in `<iomanip>`:

```
SMANIP, IMANIP, OMANIP, IOMANIP,
SAPP, IAPP, OAPP, IOAPP,
SMANIPREF, IMANIPREF, OMANIPREF, IOMANIPREF,
SAPPREF, IAPPREF, OAPPREF, IOAPPREF
```

You can add them yourself, but their use will not be portable.

- The `streambuf::stossc()` function, which advances the get pointer forward by one character in a stream buffer, is not available in the ANSI iostream library. You can make use of the `std::streambuf::sbumpc()` function to move the get pointer forward one place. This function returns the character it moved past. These two functions are not exactly equivalent – if the get pointer is already beyond the end, `stossc()` does nothing, and `sbumpc()` returns EOF.

```
istream &extract(istream &is)
{
    ...
    is.rdbuf()->stossc();
}
```

- `ios::bitalloc()` is no longer available in the ANSI iostream library.
- The `filebuf` constructors have changed in the ANSI iostream library. The pre-ANSI `filebuf` class contained three constructors:

```
class filebuf : public streambuf
{
    filebuf();
    filebuf(int fd);
    filebuf(int fd, char * p, int len);
    ...
}
```

In the ANSI iostream library, `filebuf` is a typedef for `basic_filebuf<char>`, and the C++ Working Paper defines one `filebuf` constructor:

```
basic_filebuf();
```

On Alpha and IA-64 systems, to facilitate backward compatibility, the ANSI iostream library does provide `basic_filebuf(int fd)` as an extension. However, the use of extensions is not portable.

For example, consider the `filebuf` constructors in the following pre-ANSI iostream library program:

```
#include <fstream.hxx>

int main () {
    int fd = 1;
    const int BUFLen = 1024;
    char buf [BUFLen];
    filebuf fb(fd,buf,BUFLen);
    filebuf fb1(fd);
    return 0;
}
```

To be strictly ANSI conforming, you would need to recode as follows:

```
filebuf fb(fd,buf,BUFLen); as filebuf fb(); and
filebuf fb1(fd); as filebuf fb1();
```

If you want to make use of the ANSI iostream `filebuf(fd)` extension, you could recode:

```
filebuf fb(fd,buf,BUFLen); as filebuf fb(fd); and
filebuf fb1(fd); as filebuf fb1(fd);
```

- **Alpha and IA-64 only:** The ANSI iostream library contains support for the `filebuf::fd()` function, which returns the file descriptor for the `filebuf` object and EOF if the `filebuf` object is closed as a nonportable extension. This function is not supported under the /STANDARD=STRICT\_ANSI compiler mode. ♦
- The following functions are not defined in the ANSI iostream library. They are provided in the ANSI iostream library for backward compatibility only. Their use is not portable.

```
ifstream::ifstream(int fd);
ifstream::ifstream(int fd, char *p, int len)
ofstream::ofstream(int fd);
ofstream::ofstream(int fd, char *p, int len);
```

```
fstream::fstream(int fd);  
fstream::fstream(int fd, char *p, int len);
```

- The following attach functions, which attach, respectively, a filebuf, fstream, ofstream, and ifstream to a file are not available in the ANSI iostream library:

```
filebuf::attach(int);  
fstream::attach(int);  
ifstream::attach(int);  
ofstream::attach(int);
```

If you do not want to make use of ANSI iostream library extensions, you must recode the use of attach as follows:

Change from:

```
#include <fstream.hxx>  
#include <stdio.h>  
#include <fcntl.h>  
int main () {  
    int fd;  
    fd = open("t27.in", O_RDWR | O_CREAT, 0644);  
    ifstream ifs;  
    ifs.attach(fd);  
    fd = creat("t28.out", 0644);  
    ofstream of;  
    of.attach(fd);  
    return 0;  
}
```

To:

```
#include <fstream>  
int main () {  
    ifstream ifs("t27.in", ios::in | ios::out);  
    ofstream ofs("t28.out");  
    return 0;  
}
```

- The ios enumerators for controlling the opening of files, ios::nocreate and ios::noreplace, are not available in the ANSI iostream library.
- The istream\_withassign and ostream\_withassign classes are not available in the ANSI iostream library.
- In the ANSI iostream library ios\_base::width() applies to all formatted inserters including operator<<(char). This means that the stream width specified by either the manipulator setw() or the ios\_base::width() member function will apply padding to the next output item even if it is a char.

This was not the case in the pre-ANSI iostream library, where width() applied to all formatted inserters *except* the char inserter. The reasons for the change (to allow ostream::operator<<(char) to do formatting) are:

1. It allows operator<< functions to do formatting consistently.
2. It allows operator<<(char) and put(char) (formatted and unformatted operations on char) to have different functionality.

Consider the following example:

```
#ifdef __USE_STD_Iostream
#include <iostream>
#include <iomanip>
#else
#include <iostream.hxx>
#include <iomanip.hxx>
#endif
int main () {
    cout.width(10);
    cout.fill('^');
    cout << 'x' << '\n';
    cout << '[' << setw(10) << 'x' << ']' << endl;
    return 0;
}
```

In the ANSI iostream library the output is:

```
^^^^^^^x
[^^^^^^^x]
```

In the pre-ANSI iostream library the output is:

```
x
[x]^^^^^^^
```

- In the pre-ANSI iostream library, printing `signed char *` or a `unsigned char *` printed the address of the string. In the ANSI iostream library the string is printed. Consider the following example:

```
#ifdef __USE_STD_Iostream
#include <iostream>
#else
#include <iostream.hxx>
#endif

int main () {
    char * cs = (char *) "Hello";
    signed char *ss = (signed char *) "world";
    unsigned char *us = (unsigned char *) "again";

    cout << cs << " " << ss << " " << us << endl;
    return 0;
}
```

The output in the ANSI iostream library is:

```
Hello world again
```

The output in the pre-ANSI iostream library is:

```
Hello 0x120001748 0x120001740
```

To obtain output equivalent to the pre-ANSI iostreams, you might do the following:

```
cout << hex << showbase << (long) ss << " "
```



```
<< (long) us << endl;
```

- In the pre-ANSI iostream library printing a signed char prints its integer value. In the ANSI iostream library printing a signed char prints it as a character. Consider the following example:

```
#ifndef __USE_STD_Iostream
#include <iostream>
#else
#include <iostream.hxx>
#endif

int main () {
    signed char c = (signed char) 'c';
    cout << c << endl;
    return 0;
}
```

The output in the ANSI iostream library is:

c

The output in the pre-ANSI iostream library is:

99

To obtain output equivalent to the pre-ANSI iostreams, you must do the following:

```
cout << (long) c << endl;
```

- In the ANSI iostream library, reading invalid floating point input (where invalid input is caused by no digits following the letter e or E and an optional sign) from a stream sets failbit to flag this error state. In the pre-ANSI iostream library, these type of error conditions might not be detected. Consider this program fragment:

```
double i;
cin >> i;
cout << cin.rdstate() << ' ' << i << endl;
```

On the input: 123123e

The output in the ANSI iostream library is:

```
4 2.65261e-314          // failbit set
```

The output in the pre-ANSI iostream library is:

```
0 123123                // goodbit set
```

- In the ANSI iostream library, reading integer input (which is truncated as the result of a conversion operation) from a stream sets failbit to flag this overflow condition. In the pre-ANSI iostream library, these types of conditions might not be detected. Consider this program fragment:

```
int i;
cin >> i;
cout << cin.rdstate() << ' ' << i << endl;
```

On the input: 9999999999999999

The output in the ANSI iostream library is:

```
4 1874919423          // failbit set
```

The output in the pre-ANSI iostream library is:

```
0 1874919423          // failbit not set
```

In the ANSI iostream library, reading -0 from a stream into an unsigned int outputs 0; this was not the case with the pre-ANSI iostream library. Consider the following:

```
unsigned int ui;
cin >> ui;
cout << cin.rdstate() << ' ' << ui << endl;
```

On the input: -0

The output in the ANSI iostream library is:

```
0 0
```

- In the ANSI iostream library, the `istream::getline()` function extracts characters and stores them into successive locations of an array whose first element is designated by `s`. If fewer than `n` characters are input, failbit is set. This was not the case in the pre-ANSI iostream library. Consider the following:

```
#include <stdlib.h>
int main()
{
    char buffer[10];
    cin.getline (buffer,10);
    cout << cin.rdstate() << ' ' << buffer << endl;
    return EXIT_SUCCESS;
}
```

With input of: 1234567890

The output in the ANSI iostream library is:

```
4 123456789
```

The output in the pre-ANSI iostream library is:

```
0 123456789
```

- When printing addresses, the ANSI library does not print a leading “0x” to indicate a hexadecimal base. The pre-ANSI library did. Consider the following:

```
#include <stdlib.h>
#include <iostream>

int main()
{
    double d;
    int i;
    void *p = (void *) &d;
    int *pi = &i;
    cout << (void *) 0 << ' ' << p << ' ' << pi << endl;
    return EXIT_SUCCESS;
}
```

```
}
```

The output in the ANSI iostream library is:

```
0 11fffe7a0 11fffe798
```

The output in the pre-ANSI iostream library is:

```
0x0 0x11fffdc40 0x11fffdc38
```

- `basic_filebuf::setbuf` is a protected member function in the ANSI iostream library. Therefore, the following no longer compiles:

```
#include <fstream>
int main() {
    filebuf fb;
    ...
    fb.setbuf(0,0);
    return EXIT_SUCCESS;
}
```

- In the ANSI iostream library, the Standard C++ streams are synchronized with the Standard C streams by default. Calling `sync_with_stdio()` with `false` allows the Standard C++ streams to operate independently of the Standard C streams. In the pre-ANSI iostream library the Standard C++ streams are **not** synchronized with the Standard C streams by default.

You notice the consequences of this change if you redirect the output of a program using the Standard C++ streams to a log file by entering the following commands at the DCL prompt:

```
$ define sys$output t.out
$ run program
$ deassign sys$output
```

For example, if you write something like this using ANSI iostreams:

```
#ifndef __USE_STD_Iostream
#define __USE_STD_Iostream
#endif
#include <iostream>
void main () {
    int s = 5;
    cout << "i" << s;
}
```

and if you redirect the output to a log file using the commands shown in the example, the log file contains two records:

- On Alpha and IA-64:

```
i
5
```

- On x86-64:

```
i5
```

If you write something like this using pre-ANSI iostreams:

```
#include <iostream.hxx>
```

```
void main () {  
    int s = 5;  
    cout << "i" << s;  
}
```

and if you redirect the output to a log file using the commands shown in the example, the log file contains one record: `i5`.

To obtain the Pre-ANSI iostreams behavior with ANSI iostreams, you can use either of the following workarounds:

- Redirect your output to a file by entering the following commands:

```
$ define/user sys$output t.out  
$ run program
```

The output of the log file, `t.out`, contains one record: `i5`.

- Recode your program so that the Standard C++ streams operate independently of the Standard C streams. Do this by calling `sync_with_stdio()` with a `false` argument as follows:

```
#include <stdlib.h>  
#ifndef __USE_STD_IOSTREAM  
#    define __USE_STD_IOSTREAM  
#endif  
#include <iostream>  
int main () {  
    ios_base::sync_with_stdio(false);  
    int s = 5;  
    cout << "i" << s;  
    return EXIT_SUCCESS  
}
```

If you now redirect the output to a log file, the log file contains one record: `i5`.

# Chapter 9. Using the OpenVMS Debugger

A debugger helps you find run-time errors by letting you observe and interactively manipulate program execution step by step, until you discover where the program functions incorrectly. The OpenVMS Debugger is symbolic, meaning that you can refer to symbolic names for the memory addresses allocated to variables, routines, labels, and so on. You need not use virtual addresses.

The language of the source program you are currently debugging determines the format you use to enter and display data. The language also determines the format used for features, such as comment characters, operators, and operator precedence, which have language-specific settings. However, if you have modules written in another language, you can switch from one language to another during your debugging session.

## 9.1. Debugging C++ Programs

The OpenVMS Debugger supports the language constructs of C++ and other debugger-supported programming languages. This section describes features specific to debugging C++ programs. For more information on the OpenVMS Debugger, see the *VSI OpenVMS Debugger Manual*.

### 9.1.1. Compiling and Linking for Debugging

To use the debugger, compile and link your program with the `/DEBUG` (Alpha and IA-64 only) qualifier on both commands. On the compiler command, the `/DEBUG` qualifier writes into the object module the debug symbol records declared in the program source file. These records make the names of variables and other declared symbols accessible to debugger commands. If your program has several compilation units, make sure you use the `/DEBUG` qualifier to compile each unit you want to debug.

On OpenVMS IA-64 systems, specifying `/DEBUG` gives you `/DEBUG=(TRACEBACK,SYMBOLS=BRIEF)`, which omits debug information for unused labels and unused types, even when `/NOOPTIMIZE` is specified. This feature results in much smaller object files. To include unused labels and types, specify the `SYMBOLS=NOBRIEF` keyword explicitly (`/DEBUG=(SYMBOLS=NOBRIEF)`).

On OpenVMS Alpha systems, specifying `/DEBUG` gives you `/DEBUG=(TRACEBACK,SYMBOLS)`, which effectively gives you `/DEBUG=(TRACEBACK,SYMBOLS=NOBRIEF)`.

Additionally, use the `/NOOPTIMIZE` qualifier with the compiler command. Optimized code can reduce program size and increase execution speed, but can also create inconsistencies in memory content that adversely affects debugging. Use the default `/OPTIMIZE` qualifier only with programs that have been completely debugged.

On the linker command, the `/DEBUG` qualifier incorporates into the executable image all the symbol information contained in the object modules. Using the `/DEBUG` qualifier on the linker command also starts the debugger at run time.

### 9.1.2. Debugger Support

Additionally, compilation with normal (full) optimization will have the following noticeable effects:

- Stepping by line will generally seem to bounce forward and back, due to the effects of code scheduling. The general drift will definitely be forward, but initial experience indicates that the effect will be very close to stepping by instruction.
- Variables that are “split” (so that they are allocated in more than one location during different parts of their lifetimes) may not be described correctly.

Although not handled quite like normal split variables, formal parameters that are passed in registers share many of the same problems as split variables. Even with the `/NOOPTIMIZE` qualifier, such a parameter often will be copied immediately to a “permanent home” (either on the stack or in some other register) during the routine prolog. The debugger symbol table description of such parameters encodes this permanent home location and *not* the physical register in which the parameter is passed. The end-of-prolog location is recorded in the debugger symbol tables and will be used as the preferred breakpoint location when a breakpoint is set in the context of an appropriately set module (so that symbol table information is available to the debugger).

## Debugger Command-Line Options (Alpha and IA-64 only)

The compiler provides a set of debugger options that you can specify to the `/DEBUG` qualifier on the compiler command line. These options determine the kind of information that the compiler places in the object module for use by the OpenVMS Debugger. These debugger options include using traceback records and using the debugger symbol table. For more information, see the `/DEBUG` qualifier in *Appendix A, “Compiler Command Qualifiers”*.

### 9.1.3. Starting and Ending a Debugging Session

When you enter the DCL `run` command and specify your executable image file, the OpenVMS Debugger takes control. The debugger displays a message indicating its version, the programming language the source code is written in, and the name of the image file. When the `DBG>` prompt appears, you can enter debugger commands.

To execute the program, enter the debugger `go` command. Execution proceeds until the debugger pauses or stops the program (for example, to prompt you for user input, to signal an error, or to inform you that your program completed successfully).

To interrupt the debugging session in progress, press `Ctrl/C`. The `DBG>` prompt displays and you can again enter debugger commands.

To end a debugging session, enter the debugger `exit` command or press `Ctrl/Z`.

### 9.1.4. Features Basic to Debugging C++ Programs

This section describes features essential for debugging C++ programs.

#### 9.1.4.1. Determining Language Mode

The OpenVMS Debugger is in C++ language mode when invoked against a main program or routine written in C++. If you are debugging an application with modules written in some language other than C++, you may switch back to C++ language mode by using the command `set language c_plus_plus`.

You can use the `show language` command to determine the language mode set. For example:

```
DBG> show language
language: C_PLUS_PLUS
DBG>
```

### 9.1.4.2. Built-In Operators

This section describes the built-in operators that you can use in debugger commands. The operators in C++ language expressions are as follows:

Symbol	Function	Kind
*	Indirection	Prefix
&	Address of	Prefix
sizeof	size of	Prefix
–	Unary minus (negation)	Prefix
+	Addition	Infix
–	Subtraction	Infix
*	Multiplication	Infix
/	Division	Infix
%	Remainder	Infix
<<	Left shift	Infix
>>	Right shift	Infix
==	Equal to	Infix
!=	Not equal to	Infix
>	Greater than	Infix
>=	Greater than or equal to	Infix
<	Less than	Infix
<=	Less than or equal to	Infix
~ (tilde)	Bit-wise NOT	Prefix
&	Bit-wise AND	Infix
	Bit-wise OR	Infix
^	Bit-wise exclusive OR	Infix
!	Logical NOT	Prefix
&&	Logical AND	Infix
	Logical OR	Infix

Because the exclamation point (!) is an operator, it cannot be used in C++ programs as a comment delimiter. However, to permit debugger log files to be used as debugger input, the debugger still recognizes the exclamation point as a comment delimiter if it is the first nonspace character on a line. In C++ language mode, the debugger accepts a forward slash immediately followed by an asterisk (/\*) as the comment delimiter. The comment continues to the end of the current line. A matching asterisk immediately followed by a slash (\*/) is neither needed nor recognized.

The debugger accepts the asterisk (\*) prefix as an indirection operator in both C++ language expressions and debugger address expressions. In address expressions, the asterisk prefix is synonymous to the period (.) prefix or the at sign (@) prefix when the language is set to C++.

To prevent unintended modifications to the program being debugged, the debugger does not support any of the assignment operators in C++ (or any other language). Thus, such operators as =, +=, −, ++, and −− are not recognized. To alter the contents of a memory location, you must do so with an explicit `deposit` command.

### 9.1.4.3. Constructs in Language and Address Expressions

The supported constructs in language and address expressions for C++ are as follows:

Symbol	Construct
[ ]	Subscripting
. (period)	Structure component selection
->	Pointer dereferencing

### 9.1.4.4. Data Types

Predefined data types supported in the debugger are as follows:

C++ Data Type	OpenVMS Data Type Name
int	Longword Integer
long	Longword Integer (Alpha and IA-64), Quadword Integer (x86-64)
unsigned int	Longword Unsigned
unsigned long	Longword Unsigned, Quadword Integer (x86-64)
long long	Quadword Integer
unsigned long long	Quadword Unsigned
short int	Word Integer
unsigned short int	Word Unsigned
char	Byte Integer
unsigned char	Byte Unsigned
float	F_Floating (Alpha default), S_Floating (IA-64 and x86-64 default)
double	G_Floating (Alpha default), T_Floating (IA-64 default), D_Floating
enum	None
struct	None
union	None
class	None
Pointer type	None
Array type	None

Uppercase letters in parentheses represent standard data type mnemonics in the OpenVMS common language environment. For more information, see *OpenVMS Programming Interfaces: Calling a System Routine*.



Supported data types specific to OpenVMS systems are as follows:

C++ Data Type	OpenVMS Data Type Name
<code>__int16</code>	Word Integer
<code>unsigned __int16</code>	Word Unsigned
<code>__int32</code>	Longword Integer
<code>unsigned __int32</code>	Longword Unsigned
<code>__int64</code>	Quadword Integer
<code>unsigned __int64</code>	Quadword Unsigned

## 9.2. Using the OpenVMS Debugger with C++ Data

This section describes how to use the OpenVMS Debugger with C++ data.

### 9.2.1. Nonstatic Data Members

This section describes how to refer to data members that are not declared static.

#### 9.2.1.1. Noninherited Data Members

To refer to a nonstatic data member that is defined directly in a C++ class (or a `struct` or `union`), use its name just as with a C language `struct` or `union` member. The following example shows the correct use of a nonstatic data member reference:

```
DBG> examine x.m, p->m
```

#### 9.2.1.2. Inherited Data Members

The debugger support distinguishes nonstatic data members inherited from various base classes by prefixing their names with a sequence of *significant* base class names on the inheritance path to the member, and then the class that the member is declared in. A base class on a path from an object to a member is significant if the base class in question is derived from using multiple inheritance. Thus, a base class is significant if it is mentioned in a base list containing more than one base specifier.

This notation generates the minimum number of base class prefixes necessary to describe the inheritance path to a base class, because it involves naming only those base classes where one must choose where to proceed next when traversing the path. When no multiple inheritance is involved, the reference has the following syntax:

```
CLASS::member
```

Specify the sequence of significant base classes in the order from the object's most derived significant class, to the significant base class closest to the object.

### 9.2.2. Reference Objects and Reference Members

Because the debugger understands the concept of reference objects and reference members to objects, you can examine a reference object or reference member directly, without dereferencing it as you would for a pointer. To access the values of objects declared with a reference, use the name of the object.

For example, consider the following code:

```
class C {
public:
    int &ref_mem;
    C(int &arg) : ref_mem(arg) {}
};

int main()
{
    int obj = 5;
    int &ref_obj = obj;
    C c(obj);
    obj = 23;
}
...
```

The following sequence shows the correct way to use the debugger to examine the members:

```
break at R8_2_3\main\%LINE 13
13: }
DBG> exam obj, ref_obj
R8_2_3\main\obj:      23
R8_2_3\main\ref_obj:  23
DBG> exam c
R8_2_3\main\c: class C
    ref_mem:      23
DBG> exam c.ref_mem
R8_2_3\main\c.ref_mem: 23
```

### 9.2.3. Pointers to Members

For Alpha systems compiled with /MODEL=ANSI and for IA-64 and x86-64 systems, a pointer to member is an offset into a structure.

Consider the following example:

```
struct A {
    int mem0;
};

struct B {
    int mem1;
    int mem2;
};

struct C : public A, public B {
    int mem3;
    int mem4;
};

/* pointer to member initialized with pointer to member
 * address of the same class.
 */
int C::*pmc = &C::mem2;
```

```
/* pointer to member initialized with pointer to member
 * address of one of the * base classes.  An implicit
 * conversion occurs.
 */
int C::*pmbc = &B::mem2;

extern "C" int printf (const char *,...);

main()
{
  C *cinst = new C;
  cinst->pmc = 7;
  printf("cinst pointer to member value is %d\n",cinst->mem2);
}
```

If you compile this program with the `/NOOPTIMIZE/DEBUG` qualifiers, from the last line in the program, you can use the pointer to member to display the following information:

```
DBG> set radix hex
DBG> exam *cinst
*EX8_2_4\main\cinst: struct C
    inherit A
        mem0: 00000000
    inherit B
        mem1: 00000000
        mem2: 0000000A
    mem3: 00000000
    mem4: 00000000

DBG> set radix hex

DBG> exa pmc
EX8_2_4\pmc: 00000008

DBG> exam pmbc
EX8_2_4\pmbc: 00000008

DBG> exam cinst
EX8_2_4\main\cinst: 0000000080000090

DBG> exam 0800000090+8
0000000080000098: 00000007
```

For the preceding sample program, the above debug sequence examines the pointer to member (`pmc` or `pmbc`) to obtain an offset into the structure, and adds this value to the address of the object (`*cinst`). In our example, this is `*cinst + the value of pmc`.

For Alpha systems compiled with the default object model (`/MODEL=ARM`), a pointer to member involves executing a piece of function-like code, called a thunk.

The argument to this function is the address of the base class containing the member. This address is obtained by adding the offset of the start of the base class to the address of the object. This offset adjustment is needed when the pointer to member refers to a multiply inherited base class.

A sample debug sequence for the previous program example follows:

```
DBG> set radix hex
DBG> sho sym /full C
```

```
type C
  struct (C, 2 components), size: 20 bytes
    inherits: A, size: 4 bytes, offset: 0000000000000000 bytes
              B, size: 8 bytes, offset: 0000000000000004 bytes
    contains the following members:
      mem3 : longword integer, size: 4 bytes, offset: 0000000000000000C
bytes
      mem4 : longword integer, size: 4 bytes, offset: 00000000000000010
bytes
DBG> exam pmc
EX8_2_4\pmc:      000100D8

DBG> exam cinst
EX8_2_4\main\cinst:      006706F0

DBG> call 000100D8(006706F0+4)
value returned is 006706F8

DBG> exam 006706F8
00000000006706F8:      00000007
```

This debug sequence first obtains the offset to the start of the nested class containing the member pointed to with `show sym /full`. In this case, the offset is 4.

It then examines the pointer to member (`pmc`) and determines the address of the object (`cinst`). In our case, `pmc = 100D8` (thunk) and `cinst = 6706F0`.

Then it calls the thunk, passing the address of the object plus the offset: `CALL 000100D8(006706F0+4)`. This call to the thunk returns the address of the member.

Finally, it examines the member (`006706F8`).

## 9.3. Using the OpenVMS Debugger with C++ Functions

This section describes how to reference the various kinds of functions and function arguments.

### 9.3.1. Referring to Overloaded Functions

You can use the debug `SHOW SYMBOL` command to see all the overloaded names for a given function. You can set breakpoints on an overloaded function by specifying either the object name and function name followed by the argument types, or by specifying the class name and function name followed by the arguments.

For example, consider the following sample program:

```
extern "C" {int printf(const char *,...);}

class base{
public:
    base(){};
    base(int){};

    ~base(){};
```

```
void base_f1() {printf("called base_f1()\n");}

void base_f2() {printf("called base_f2()\n");}
void base_f2(int) {printf("called base_f2(int)\n");}
void base_f2(char c) {printf("call base_f2(char)\n");}

};

int main()
{
    base b;
    base b1(1);
    b.base_f1();
    b.base_f2(10);
    b.base_f2();
    b.base_f2('c');
}
```

The following debug sequence for the previous sample program shows how to set breakpoints on overloaded symbols and how to list these functions:

```
DBG> s
stepped to EX8_3_1\main\%LINE 20
    20:      base b1(1);
DBG> set break base::base_f1
DBG> set break base::base_f2
%DEBUG-I-NOTUNQOVR, symbol 'base::base_f2' is overloaded
overloaded name base::base_f2
    instance base::base_f2(char)
    instance base::base_f2(int)
    instance base::base_f2()
%DEBUG-E-REENTER, reenter the command using a more precise pathname
DBG> set break base::base_f2(char)
```

## 9.3.2. Referring to Destructors

The debugger supports the following formats for setting a break on a destructor:

```
DBG> set break stack::~~stack()

DBG> set break stack::~~stack(int)
```

## 9.3.3. Referring to Conversions

The set of atomic types are drawn from the following set of names:

void	char	signed_char	unsigned_char	signed_short
unsigned_short	int	signed_int	unsigned_int	signed_long
unsigned_long	float	double	long_double	

Pointer types are named (type)\*. Reference types are named (type)&. The types struct, union, class, and enum are named by their tags, and the qualifiers const and volatile precede their types with a space in between.

## 9.3.4. Referring to User-Defined Operators

The following operators can be overloaded by user-defined functions:

+	-	*	/	%	^
&		~	!	=	<
>	+=	-=	*=	/=	%=
^=	&=	=	<<	>>	>>=
<<=	==	!=	<=	>=	&&
	++	-	->*	,	->
[]	()	delete	new		

### 9.3.5. Referring to Function Arguments

In OpenVMS Debugger referencing, you use `this`, `*this`, and `this->m` as follows:

- All nonstatic member functions have a pointer parameter available named `this`. For example:

```
DBG> examine this
```

- Use `*this` to examine the prefix object that a member function is invoked against. For example:

```
DBG> examine *this
```

- Use the `this` parameter to refer to a data member `m` of the prefix argument to a member function. For example:

```
DBG> examine this->m
```

### 9.3.6. Calling C++ Member Functions from the Debugger

When calling C++ member functions from the debugger, you cannot make the call using the same syntax that you would use in a C++ source file. You must call the class-qualified member function name with the object as the first argument.

For example:

```
extern "C" void printf(const char *,...);

class C12 {
    int i;
    int j;
public:
    static int sum;
public:
    C12() : i(1), j(2) {}
    void method();
    static int get_sum() {
        printf("called static function get_sum()\n");
        return sum;
    }
};

void C12::method()

{
```

```
        i = i + j;
        printf("C12::method called: i=%d, j=%d\n", i, j);
    }

    int C12::sum = 0;

    int main()
    {
        C12 cinst;
        cinst.method();
        C12::get_sum();
        printf("End of example.\n");
    }
```

Be aware that when a nonstatic member function is called, the compiler passes an implicit first parameter, the "this" pointer. But, when using the debugger's call instruction, you must explicitly pass this hidden first argument:

```
//Call the nonstatic member function:
DBG> call cinst.method(cinst)
C12::method called: i=3 j=2
value returned is 28
// notice that the following call confuses debug:
DBG> call cinst.method()
%DEBUG-E-MISOPEMIS, misplaced operator or missing operand at 'end of
expression'
```

However, when calling a static member function, there is no implicit this pointer and there function may be called using the class name or the object name:

```
// Call the static function:
DBG> call C12::get_sum
called static function get_sum()
value returned is 0
DBG> call cinst.get_sum
called static function get_sum()
value returned is 0
```





# Chapter 10. Using 64-bit Address Space

This chapter describes 64-bit address support for the VSI C++ compiler.

The introduction of 64-bit address space in OpenVMS greatly increases the amount of memory available to applications. VSI C++ has been enhanced to permit use of this memory. The compiler provides a great deal of flexibility about how this memory can be used. Conceptually, this flexibility can be viewed as four models for development:

- 32-bit development
- 64-bit development
- 32-bit development with long pointers
- 64-bit development with short pointers

In a 32-bit development environment, all pointers are 32-bits long and only 2 gigabytes of address space is available. The default for Alpha and IA-64 is 32-bits long development environment. The default for x86-64 is 64-bits long development environment. In a 64-bit development environment, all pointers are 64-bits long and the address space is over a billion gigabytes.

Working in a homogeneous 32-bit or 64-bit environment is the preferred and recommended way to do development. VSI C++ for OpenVMS, combined with the C Run-Time library, provide a seamless environment for development. It should be possible for a well written, portable program developed using 32-bit pointers to be recompiled and relinked to use 64-bit pointers.

Because it is not always possible or desirable to work in a homogeneous pointer environment. VSI C++ supports mixed pointer sizes, however, it requires greater care by developers. Some contexts where heterogeneous pointer sizes might be used are:

- Memory requirements of 32-bit application exceeds 2 gigabytes
- Access to a legacy 32-bit library is required from a 64-bit application
- The memory foot print of a 64-bit application needs to be reduced

When the memory requirements of a 32-bit application begins to exceed 2 gigabytes, the most straight forward solution is to convert the application to be a 64-bit application. Since practical considerations, like the size of the application or the lack of source code for all parts can prevent this, the alternative approach of isolating the use of 64-bit pointers to a small portion of the application may be preferable. In this situation, development would continue in the 32-bit environment, using long pointers when necessary.

When doing 64-bit development, there are times when it becomes necessary or desirable to use 32-bit pointers. The most common instance is interfacing with a 32-bit library. Another is to save space, because 64-bit pointers consume twice as much memory as 32-bit pointers. In this situation, development could be done in a 64-bit environment, using short pointers when necessary.

Limited empirical evidence suggests that using 32-bit pointers to save space can reduce memory consumption by approximately 25% but at the cost of greater complexity and the creation of potentially unnecessary constraints in the application.

## 10.1. 32-bit Versus 64-bit Development Environment

Besides pointer size, the following components of the development environment determine whether it is a 32- or 64-bit environment:

- Memory allocators
- Libraries

Memory allocators control where in the address space memory is allocated. Memory can be allocated in 32- or 64-bit space independent of the pointer size. The default memory allocator is appropriate for the development environment being used.

Libraries in a 32-bit environment expect pointers to be 32-bits and memory to reside in the 32-bit address space, while libraries in the 64-bit environment expect pointers to be 64-bits.

On OpenVMS Alpha and IA-64, VSI C++ for OpenVMS uses with two libraries: one for the 32-bit environment and one for the 64-bit environment. In addition to supporting the 64-bit environment, the second library also supports the new object model referred to as model ANSI.

On OpenVMS x86-64, VSI C++ uses only one library for the 64-bit environment, but also provides allocators for 32-bit address allocation.

/MODEL=ANSI only affects the pointer size on Alpha systems. The qualifier is silently ignored on IA-64 and x86-64 systems.

---

### Caution

**Alpha and IA-64 only:** When compiling /POINTER\_SIZE=LONG, the STL template classes (such as string, and set, map) can be used only when /MODEL=ANSI is specified. ♦

---

The C Run-Time Library is a single library that supports both environments. See the [VSI C Run-Time Library Reference Manual for OpenVMS Systems \[https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/\]](https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/) for information about how support for both environments was achieved with a single library. See *Section 10.6, "Avoiding Problems"* for a discussion of why it is difficult to produce a single C++ library to support both environments.

### 10.1.1. Model ANSI (Alpha only)

The new ANSI object model allows the compiler to better conform to the ANSI/ISO C++ standard while providing the 64-bit development environment. This object model is specified using the /MODEL=ANSI compiler and link options. /MODEL=ANSI only affects the pointer size on Alpha systems. The qualifier is silently ignored on IA-64 systems.

To build a 64-bit application using the ANSI object model, you enter commands in the following format:

```
$ cxx /model=ansi filename.cxx
$ cxxlink/model=ansi filename
```

---

### Caution

The new ANSI object model is not compatible with the old object model. You must compile and link your entire application with one model or the other.

---

## 10.1.2. Memory Allocators (Alpha and IA-64 only)

In C++, the primary memory allocator is `new`. Use of the default allocators causes memory to be allocated that is appropriate for the default pointer size for the module (not the current pointer size). Specialized placement-`new` allocators can be used to control where an object is allocated. The header `newext.h` contains the following definitions:

```
enum addr32_t {addr_32 };
enum addr64_t {addr_64 };

#pragma pointer_size short
void *operator new(addr32_t, size_t s) { return _malloc32(s); }
void *operator new[](addr32_t, size_t s) { return _malloc32(s); }

#pragma pointer_size long
void *operator new(addr64_t, size_t s) { return _malloc64(s); }
void *operator new[](addr64_t, size_t s) { return _malloc64(s); }
```

The x86-64 CXX operator **new** causes memory to be allocated in the address space corresponding to the current pointer size.

Use of the allocators from the C Run Time is also possible. You can select a specific C allocator by adding a prefix underbar and either 32 or 64 as a suffix.

Function	32-bit	64-bit
<code>malloc</code>	<code>_malloc32</code>	<code>_malloc64</code>
<code>calloc</code>	<code>_calloc32</code>	<code>_calloc64</code>
<code>realloc</code>	<code>_realloc32</code>	<code>_realloc64</code>
<code>strdup</code>	<code>_strdup32</code>	<code>_strdup64</code>

When attempting to mix pointer sizes in your program, distinguish between the concepts of pointer size and memory allocators. The pointer size dictates the maximum amount of address space a pointer can reference, while the allocator controls the where the memory will be allocated.

A library implemented with 64-bit pointers that uses only a 32-bit allocator can with care be used by an application that uses 32-bit pointers. If the library uses a 64-bit allocator, the application cannot reference any pointers returned. To a large extent, it is the memory allocator, not the pointer size, that determines interoperability.

## 10.1.3. 64-bit Pointer Support in the C Run Time Library

In addition to allocators, other functions in the C Run Time Library, such as `strcpy`, are affected by pointer size. As with the allocators, the C++ compiler calls a version of the routine is for the development environment. See the [VSI C Run-Time Library Reference Manual for OpenVMS Systems](https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/) [<https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/>] for more details.

## 10.2. Qualifiers and Pragmas

The following qualifiers, pragmas, and predefined macros control pointer size:

- `/MODEL=ANSI` (Alpha only)
- `/[NO]POINTER_SIZE={LONG | SHORT | 64 | 32}`
- `#pragma pointer_size`
- `#pragma required_pointer_size`
- `#pragma environment cxx_header_defaults` (Alpha and IA-64 only)
- `__INITIAL_POINTER_SIZE` predefined macro

### 10.2.1. The `/MODEL=ANSI` Qualifier (Alpha only)

The `/MODEL=ANSI` qualifier enables the new ANSI object model. This model implies `/POINTER_SIZE=LONG` in addition to supporting new C++ constructs that could not be supported in the object model designed to support the ARM definition of the language. This option must be specified during compilation and linking. `/MODEL=ANSI` only affects the pointer size on Alpha systems. The qualifier is silently ignored on IA-64 systems.

### 10.2.2. The `/POINTER_SIZE` Qualifier

The `/POINTER_SIZE` qualifier lets you specify a value of 64 or 32 (or `LONG` or `SHORT`) as the default pointer size within the compilation unit. You can compile one set of modules using 32-bit pointers and another set using 64-bit pointers. Take care when these two separate groups of modules call each other.

The default is `/NOPOINTER_SIZE`, which has the following effects:

- Disables pointer-size features, such as the ability to use `#pragma pointer_size`
- Directs the compiler to assume that all pointers are 32-bit pointers for Alpha and IA-64, and 64-bit pointers for x86-64 CXX

This default represents no change from previous versions of VSI C++ Alpha and IA-64. For the x86-64, the default was changed from 32-bit to 64-bit.

Specifying `/POINTER_SIZE` with a keyword value (32, 64, `SHORT`, or `LONG`) has the following effects:

- Enables processing of `#pragma pointer_size`.
- Sets the initial default pointer size to 32 or 64, as specified.
- Predefines the preprocessor macro `__INITIAL_POINTER_SIZE` to 32 or 64, as specified. If `/POINTER_SIZE` is omitted from the command line, `__INITIAL_POINTER_SIZE` is 0, which allows you to use `#ifdef __INITIAL_POINTER_SIZE` to test whether the compiler supports 64-bit pointers.
- For `/POINTER_SIZE=64`, the C RTL name mapping table is changed to select the 64-bit versions of `malloc`, `calloc`, and other RTL routines by default.

On OpenVMS x86-64, `/NOPOINTER_SIZE` also causes the 64-bit RTL functions to be selected.

Use of the `/POINTER_SIZE` qualifier also influences the processing of C RTL header files:

- For those functions that have both 32-bit and 64-bit implementations, specifying `/POINTER_SIZE` enables function prototypes to access both functions, regardless of the actual value supplied to the qualifier. The value specified to the qualifier determines the default implementation to call during that compilation unit.

On OpenVMS x86-64, the `#pragma` directive does not affect C RTL function name mapping. Both 32-bit and 64-bit versions of these functions remain accessible.

- Functions that require a second interface to be used with 64-bit pointers reside in the same object libraries and shareable images as their 32-bit counterparts. Because no new object libraries or shareable images are introduced, using 64-bit pointers does not require changes to your link command or link options files.

See the *VSI C Run-Time Library Reference Manual for OpenVMS Systems* [<https://docs.vmssoftware.com/vsi-c-run-time-library-reference-manual-for-openvms-systems/>] for more information on the impact of 64-bit pointer support on VSI C++ RTL functions.

### 10.2.3. The `__INITIAL_POINTER_SIZE` Macro

The `__INITIAL_POINTER_SIZE` preprocessor macro is useful for header-file authors to determine:

- Whether the compiler supports 64-bit pointers.
- Whether the application expects to use 64-bit pointers.

Header-file code can then be conditionalized using the following preprocessor directives:

```
#if defined (__INITIAL_POINTER_SIZE) /* Compiler supports
                                     64-bit pointers */
#if __INITIAL_POINTER_SIZE > 0 /* /POINTER_SIZE qualifier is
                               provided with [32 | SHORT] or [64 | LONG] values. */
#if __INITIAL_POINTER_SIZE == 32 /* Application uses some
    64-bit pointers, but default RTL routines are 32-bit.*/

#if __INITIAL_POINTER_SIZE == 64 /* Application uses 64-bit
pointers and default RTL routines are 64-bit. */
```

### 10.2.4. Pragmas

The `#pragma pointer_size`, `#pragma required_pointer_size`, and preprocessor directives can be used to change the pointer size currently in effect within a compilation unit. You can default pointers to 32-bits and then declare specific pointers within the module as 64-bits. In this case, you also need to specifically call the appropriate allocator to obtain memory from the 64-bit memory area.

These pragmas have the following format:

```
#pragma pointer_size keyword

#pragma required_pointer_size keyword
```

The *keyword* is one of the following:

<code>{short 32}</code>	32-bit pointer
-------------------------	----------------

<code>{longl64}</code>	64-bit pointer
<code>save</code>	Saves the current pointer size
<code>restore</code>	Restores the current pointer size to its last saved state

The `#pragma pointer_size` and `#pragma required_pointer_size` directives work essentially the same way, except that `#pragma required_pointer_size` always takes effect regardless of command-line qualifiers, while `#pragma pointer_size` is in effect only when the `/POINTER_SIZE` command-line qualifier is used.

By changing the command-line qualifier, `#pragma pointer_size` allows a program to be built using 64-bit features as purely as a 32-bit program.

The `#pragma required_pointer_size` is intended for use in header files where interfaces to system data structures must use a specific pointer size regardless of how the program is compiled.

### Alpha and IA-64 only

An alternative to control the pointer size is `#pragma environment`. This pragma controls all compiler states that include pointer size. This pragma is fully documented in *Section 2.1.1.3, "#pragma environment Directive (Alpha and IA-64 only)"*. The primary change for support of long pointers is the addition of a new **`cxx_header_defaults`** keyword.

This new keyword is similar to the **`header_defaults`** keyword, but differs in the effect on `pointer_size`. With **`header_defaults`**, `pointer_size` is made short, while with **`cxx_header_defaults`**, the `pointer_size` depends on the model being used. When developing in model ANSI, the `pointer_size` is 64 bits; in model ARM (the default), it is 32 bits.

## 10.3. Determining Pointer Size

On Alpha and IA-64, the pointer-size qualifiers and pragmas affect only a limited number of constructs in the C++ language itself. At places where the syntax creates a pointer type, the pointer-size context determines the size of that type. Pointer-size context is defined by the most recent pragma (or command-line qualifier) affecting pointer size.

On x86-64 C++, the pointer-size handling mechanism behavior is extended. For more details refer to the *x86-64 C++ Release Notes*.

Here are examples of places in the syntax where a pointer type is created:

- The `*` in a declaration or cast:

```
int **p; // Declaration
ip = (int **)i; // Cast
```

- The outer (leftmost) brackets `[]` in a formal parameter imply a `*`:

```
void foo(int ia[10][20]) {}

// Means the following:

void foo(int (*ia)[20]) {}
```

- A function declarator as a formal parameter imply a `*`:

```
void foo (int func()):  
  
// Means the following:  
  
void foo (int (*)() func);
```

- Any formal parameter of array or function type implies a \*, even when bound in a typedef:

```
typedef int a_type[10];  
  
void foo (a_type ia);  
  
// Means the following:  
  
void foo (int *ia);
```

### 10.3.1. Special Cases

The following special cases are not affected by pointer-size context:

- Formal parameters to `main` are always treated as if they were in a `#pragma pointer_size system_default` context, which is 32-bit pointers for OpenVMS systems.

For example, regardless of the `#pragma pointer_size 64` directive, `argv[0]` is a 32-bit pointer:

```
#pragma pointer_size 64  
  
int main(int argc, char **argv)  
{ ASSERT(sizeof(argv[0]) == 4); }
```

**IA-64 and x86-64 only:** Note that using `/POINTER_SIZE=LONG=ARGV` allows `argv` to be a pointer to long pointers. ♦

- A string literal produces a pointer based on the current pointer size when used as an rvalue (Alpha only):

```
#pragma pointer_size 64  
  
ASSERT(sizeof("x" + 0) == 8);  
  
#pragma pointer_size 32  
  
ASSERT(sizeof("x" + 0) == 4);
```

- The `&` operator yields a pointer based on the current pointer size unless it is applied to pointer dereference, in which case it is the size of the dereferenced pointer type:

```
#pragma pointer_size 32  
sizeof(&foo) == 4  
  
#pragma pointer_size 64  
sizeof(&foo) == 8  
  
sizeof(&s ->next) == sizeof(s)
```

- **Alpha and IA-64 only**

The size of `this` pointer depends on the size in effect at the point of the member's signature definition, not on the use of the pointer.

```
class foo {
public:
    void f();
    void f2();
};

#pragma required_pointer_size short
void foo::f()
{ sizeof(this)==4 } // this is short

#pragma required_pointer_size long
void foo::f2()
#pragma required_pointer_size short
{ sizeof(this)==8; } // this is long
```

- On x86-64 architectures, the `this` pointer is always 64-bits in size and cannot be changed.

### 10.3.2. Mixing Pointer Sizes

An application can use both 32-bit and 64-bit addresses. The following semantics apply when mixing pointers:

- Assignments (including arguments) silently promote a 32-bit pointer rvalue to 64 bits if other type rules are met. Promotion means sign extension.
- A warning is issued for an assignment of a 64-bit rvalue to a 32-bit lvalue (without an explicit cast).
- For purposes of type compatibility, a different size pointer is a different type (for example, when matching a prototype to a definition, or other contexts involving redeclaration), however, overloading is not permitted.
- The debugger knows the difference between pointers of different sizes.

## 10.4. Header File Considerations

Take note of the following general header-file considerations:

- Header files usually define interfaces with types that must match the layout used in library modules.
- Header files often do not bind “top-level” pointer types. Consider, for example:

```
fprintf(FILE *, const char *, ...);
```

A “`FILE * fp;`” in a declaration in a different area of source code might be a different size.

- All pointer parameters occupy 64 bits in the calling sequence, so a top-level mismatch of this kind is acceptable if the called function does not lose the high bits internally.
- Routines dealing with pointers to pointers (or data structures containing pointers) cannot be enabled to work simply by passing them both 32-bit and 64-bit pointers. You need separate 32-bit and 64-bit variants of the routine.



Be aware that pointer-size controls are not unique in the way they affect header files; other features that affect data layout have similar impact. For example, most header files should be compiled with 32-bit pointers regardless of pointer-size context. Also, most system header files must be compiled with `member_alignment` regardless of user pragmas or qualifiers.

To address this issue more generally, you can use the `pragma environment` (Alpha and IA-64 only) directive to save context and set header defaults at the beginning of each header file, and then to restore context at the end. See *Section 2.1.1.3, "#pragma environment Directive (Alpha and IA-64 only)"* for a description of `pragma environment`.

For header files that have not yet been upgraded to use `#pragma environment`, the `/POINTER_SIZE=64` qualifier can be difficult to use effectively. For such header files, the compiler automatically applies user-defined prologue and epilogue files before and after the text of the included header file. See *Section 10.5, "Prologue/Epilogue Files"* for more information on prologue/epilogue files.

## 10.5. Prologue/Epilogue Files

VSI C++ automatically processes user-supplied prologue and epilogue header files. This feature is an aid to using header files that are not 64-bit aware within an application that is built to exploit 64-bit addressing.

### 10.5.1. Rationale

VSI C++ header files typically contain a section at the top that:

1. Saves the current state of the `member_alignment`, `extern_model`, `extern_prefix`, and `message` pragmas.
2. Sets these pragmas to the default values for the system.

A section at the end of the header file then restores these pragmas to their previously-saved state.

Mixed pointer sizes introduce another kind of state that typically needs to be saved, set, and restored in header files that define fixed 32-bit interfaces to libraries and data structures.

**Alpha and IA-64 only** The `#pragma environment` preprocessor directive allows headers to control all compiler states (`message suppression`, `extern_model`, `member_alignment`, and `pointer_size`) with one directive. ♦

However, for header files that have not yet been upgraded to use `#pragma environment`, the `/POINTER_SIZE=64` qualifier can be difficult to use effectively. In this case, the automatic mechanism to include prologue/epilogue files allows you to protect all of the header files within a single directory (or modules within a single text library). You do this by copying two short files into each directory or library that needs it, without having to edit each header file or library module separately.

In time, you should modify header files to either exploit 64-bit addressing (like the C RTL), or to protect themselves with `#pragma environment`. Prologue/epilogue processing can ease this transition.

### 10.5.2. Using Prologue/Epilogue Files

Prologue/epilogue file are processed in the following way:

1. When the compiler encounters an `#include` preprocessing directive, it determines the location of the file or text library module to be included. It then checks to see if one or both of the two following specially named files or modules exist in the same location as the included file:

```
__DECC_INCLUDE_PROLOGUE.H  
__DECC_INCLUDE_EPILOGUE.H
```

The location is the OpenVMS directory containing the included file or the text library file containing the included module. (In the case of a text library, the `.h` is stripped off.)

The directory is the result of using the `$PARSE/$SEARCH` system services with concealed device name logicals translated. Therefore, if an included file is found through a concealed device logical that hides a search list, the check for prologue/epilogue files is still specific to the individual directories making up the search list.

2. If the prologue and epilogue files do exist in the same location as the included file, then the content of each is read into memory.
3. The text of the prologue file is processed *just before* the text of the file specified by the `#include`.
4. The text of the epilogue file is processed *just after* the text of the file specified by the `#include`.
5. Subsequent `#includes` that refer to files from the same location use the saved text from any prologue/epilogue file found there.

The prologue/epilogue files are otherwise treated as if they had been included explicitly: `#line` directives are generated for them if `/PREPROCESS_ONLY` output is produced, and they appear as dependencies if `/MMS_DEPENDENCY` output is produced.

To take advantage of prologue/epilogue processing for included header files, you need to create two files, `__DECC_INCLUDE_PROLOGUE.H` and `__DECC_INCLUDE_EPILOGUE.H`, in the same directory as the included file.

Suggested content for a prologue file is: (Alpha and IA-64 only)

```
__DECC_INCLUDE_PROLOGUE.H:  
  
#ifdef __PRAGMA_ENVIRONMENT  
#pragma environment save  
#pragma environment header_defaults  
#else  
#error "__DECC_INCLUDE_PROLOGUE.H: This compiler does not support  
pragma environment"  
#endif
```

Suggested content for an epilogue file is:

```
__DECC_INCLUDE_EPILOGUE.H:  
  
#ifdef __PRAGMA_ENVIRONMENT  
#pragma __environment restore  
#else  
#error "__DECC_INCLUDE_EPILOGUE.H: This compiler does not support  
pragma environment"  
#endif
```

## 10.6. Avoiding Problems

Consider the following suggestions to avoid problems related to pointer size:

- Write code to work with either 32-bit or 64-bit pointers.
- Do bit manipulation on unsigned `int` and unsigned `__int64`, and carefully cast pointers to and from them.
- Heed compile-time warnings, using casts only where you are sure that pointers are not truncated.

## 10.7. Reasons for Not Using Mixed Pointer Sizes

Although VSI C and C++ allow mixing pointer sizes, mixed pointers can cause certain types of error when used incorrectly. Consider the following examples:

- Truncation

```
#pragma pointer_size long
int *y=_malloc64(); // Y is a 64-bit pointer
#pragma pointer_size short
int *x=y; // X is a 32-bit pointer, which results in truncation.
```

- Misread/miswrite

```
int i,j;
#pragma pointer_size short
int *ptr=&i;
int **pptr=&ptr;
#pragma pointer_size long
int **lptr=pptr;

*lptr = &j; // miswrite: 8 bytes write, but points to 4 byte ptr.
ptr = *lptr; // misread: 8 bytes read, but points to 4 byte ptr.
```

Furthermore, the following C++ features discourage the use of mixed pointers:

- Objects can allocate memory. Even if an object is in the 32-bit address space, the data contained in that object might not be.

```
#pragma pointer_size long
class myObject {
    char *myData;
public:
    myObject() { myData = new char[1000]; }
    ~myObject() { delete[] myData; }
    char *getData() { return myData; }
};

#pragma pointer_size short
myObject *ptr = new myObject(); //32-bit pointer to object in 32 bit
    space
char *data = ptr->getData(); //32-bit pointer truncated 64 bit pointer
    to data in 64 bit space
```

- Virtual functions make it difficult to maintain backward compatibility. Consider the following two implementations of an interface called API. One is written in C, the other in C++. With the C

implementation, you can add the new entry with the new pointer size in an upwardly compatible way. In C++, you cannot do so because the functions are virtual. Adding a virtual function to a class breaks backward compatibility. Granted, the C++ interface provides polymorphism that is not available in the C interface, but the availability of this feature is one of the reasons why applications are designed using C++.

```
// C implementation of API
void API_f1(int);
#pragma pointer_size short
void API_f2(int *);
#pragma pointer_size long
void API_f2_64(int*);
void API_f3(int);

// C++ implementation of API
class BASE {
public:
    virtual void f1(int);
#pragma pointer_size short
    virtual void f2(int *);
#pragma pointer_size long
    virtual void f2_64(int*);
};
class API : public BASE {
public:
    virtual void f3(int);
}
```

- Polymorphism semantics are difficult to define. It is easy to imagine overloading while working with mixed 32/64 bit pointers when the parameter is a simple pointer: the pointers are simply different types. However, if the pointer is embedded in a structure, how are these structures differentiated? Consider the following code fragment:

```
struct FILE {
    char *buffer;
};

FILE *fopen(const char *, , ,);
int fclose(FILE*);
```

It is easy to consider tagging the structure with a flag to indicate whether it is long or short, but it is possible for a structure to have more than one pointer definition. In that case, there could be  $2^n$  different versions of the struct. To avoid these issues, the C++ compiler treats 32 and 64 bit pointers as the same type. If you want to treat pointers as different based on size, use template classes:

```
x.cxx
-----
#include <stdio.h>
#include <iostream>
using namespace std;

#ifdef !__INITIAL_POINTER_SIZE
#error this program should be compiled with /POINTER_SIZE qualifier
#endif

template <class T>
```

```
class short_pointer {
#pragma pointer_size save
#pragma pointer_size short
    T* ptr;
public:
    short_pointer(T* x) { ptr = x; }
    operator T*() { return ptr; }
    size_t get_ptr_size() { return sizeof(ptr); }
#pragma pointer_size restore
};

template <class T>
class long_pointer {
#pragma pointer_size save
#pragma pointer_size long
    T* ptr;
public:
    long_pointer(T* x) { ptr = x; }
    operator T*() { return ptr; }
    size_t get_ptr_size() { return sizeof(ptr); }
#pragma pointer_size restore
};

template<class T>
void func(short_pointer<T> x) { *x = 5; cout << x.get_ptr_size() <<
    endl; }
template<class T>
void func(long_pointer<T> x) { *x = 5; cout << x.get_ptr_size() <<
    endl; }

int main() {
#pragma pointer_size short
    func(short_pointer<int>((int*)_malloc32(sizeof(int))));
#pragma pointer_size long
    func(long_pointer<int>((int*)malloc(sizeof(int))));
}

$ pipe cxx/pointer=short x.cxx ; cxxl x.obj ; run x.exe
4
8
$ pipe cxx/pointer=long x.cxx ; cxxl x.obj ; run x.exe
4
8
$
```



# Appendix A. Compiler Command Qualifiers

This appendix describes the qualifiers available to the CXX command.

Qualifiers indicate special actions to be performed by the compiler or special input file properties. Compiler qualifiers can apply to either the CXX command or to the specification of the file being compiled. When a qualifier follows the CXX command, it applies to all the files listed. When a qualifier follows the file specification, it applies only to the file immediately preceding it.

Table A.1, "CXX Command Qualifiers" summarizes CXX qualifiers. Detailed descriptions follow the table.

**Table A.1. CXX Command Qualifiers**

Command Qualifiers	Defaults
/[NO]ALTERNATIVE_TOKENS	See text.
/[NO]ANSI_ALIAS	/ANSI_ALIAS
/ARCHITECTURE=option	/ARCHITECTURE=GENERIC
/ASSUME=(option[,...])	See text.
/[NO]CHECK[=[NO]UNINITIALIZED_VARIABLES] ( <i>Alpha only</i> )	/NOCHECK
/CLANG=(quoted_string[,...]) ( <i>x86-64 only</i> )	N/A
/[NO]COMMENTS=option	/COMMENTS=SPACE
/[NO]DEBUG[=(option[,...])]	/DEBUG=(TRACEBACK,NOSYMBOLS)
/[NO]DEFINE=(identifier[=definition][,...])	/NODEFINE
/[NO]DEFINE=__FORCE_INSTANTIATIONS ( <i>Alpha only</i> )	/NODEFINE=__FORCE_INSTANTIATIONS
/[NO]DEFINE=__[NO_]USE_STD_Iostream	/DEFINE=__NO_USE_STD_Iostream
/[NO]DIAGNOSTICS[=file-spec]	/NODIAGNOSTICS
/[NO]DISTINGUISH_NESTED_ENUMS	/NODISTINGUISH_NESTED_ENUMS
/ENDIAN=option	/ENDIAN=LITTLE
/[NO]ERROR_LIMIT[=n]	/ERROR_LIMIT=30 ( <i>Alpha and IA-64 only</i> ) /ERROR_LIMIT=20 ( <i>x86-64 only</i> )
/EXCEPTIONS	See text.
/EXPORT_SYMBOLS ( <i>IA-64 only</i> )	See text.
/EXTERN_MODEL=option	/EXTERN_MODEL=RELAXED_REFDEF
/[NO]FIRST_INCLUDE=(file[,...])	/NOFIRST_INCLUDE
/FLOAT=option	/FLOAT=G_FLOAT ( <i>Alpha only</i> ) /FLOAT=IEEE_FLOAT ( <i>IA-64 only</i> )
/GRANULARITY=option	/GRANULARITY=QUADWORD
/IEEE_MODE[=option]	/IEEE_MODE=FAST ( <i>Alpha only</i> )

Command Qualifiers	Defaults
	/IEEE_MODE=DENORM_RESULTS ( <i>IA-64 only</i> )
/[NO]IMPLICIT_INCLUDE	/IMPLICIT_INCLUDE
/[NO]INCLUDE_DIRECTORY=(pathname[,...])	/NOINCLUDE_DIRECTORY
/L_DOUBLE_SIZE=option	/L_DOUBLE_SIZE=128
/LIBRARY	See text.
/[NO]LINE_DIRECTIVES	/LINE_DIRECTIVES
/[NO]LIST[=file-spec]	See text.
/[NO]MACHINE_CODE	/NOMACHINE_CODE
/[NO]MAIN=POSIX_EXIT	/NOMAIN
/[NO]MEMBER_ALIGNMENT	/MEMBER_ALIGNMENT
/[NO]MMS_DEPENDENCIES=[=(option[,option])]	/NOMMS_DEPENDENCIES
/MODEL={ANSI   ARM} ( <i>Alpha only</i> )	/MODEL=ARM
/NAMES=(option1,option2)	/NAMES=(UPPERCASE,TRUNCATED) ( <i>Alpha and IA-64 only</i> ) /NAMES=AS_IS ( <i>x86-64 only</i> )
/NESTED_INCLUDE_DIRECTORY[=option]	/NESTED_INCLUDE_DIRECTORY= INCLUDE_FILE
/[NO]OBJECT[=file-spec]	/OBJECT=.OBJ
/[NO]OPTIMIZE=[(option[,...])]	/OPTIMIZE
/PENDING_INSTANTIATIONS[=n]	/PENDING_INSTANTIATIONS=64
/[NO]POINTER_SIZE[=option]	/NOPOINTER_SIZE
/[NO]PREFIX_LIBRARY_ENTRIES=[(option[,...])]	See text.
/[NO]PREPROCESS_ONLY[=filename]	/NOPREPROCESS_ONLY
/PSECT_MODEL=[NO]MULTILANGUAGE	/NOMULTILANGUAGE
/[NO]PURE_CNAME	/PURE_CNAME (/STANDARD= STRICT_ANSI) /NOPURE_CNAME (All other modes)
/[NO]QUIET	/NOQUIET
/REENTRANCY=option	/REENTRANCY=TOLERANT
/REPOSITORY=option	/REPOSITORY=[.CXX_REPOSITORY]
/ROUNDING_MODE=option	/ROUNDING_MODE=NEAREST
/[NO]RTTI	/RTTI
/[NO]SHARE_GLOBALS	/NOSHARE_GLOBALS
/SHOW=[(option[,...])]	/SHOW=(HEADER,SOURCE
/STANDARD=(option,...)	/STANDARD=RELAXED
/[NO]TEMPLATE_DEFINE=[(option,...)]	See text.
/[NO]UNDEFINE=(identifier[,...])	/NOUNDEFINE
/[NO]UNSIGNED_CHAR	/NOUNSIGNED_CHAR
/[NO]USING_STD	/NOUSING_STD



Command Qualifiers	Defaults
/VERBOSE ( <i>x86-64 only</i> )	N/A
/[NO]VERSION	/NOVERSION
/[NO]WARNINGS[=(option[,...])]	/WARNINGS
/[NO]XREF[=file-spec] ( <i>Alpha only</i> )	/NOXREF

**/ALTERNATIVE\_TOKENS****/NOALTERNATIVE\_TOKENS**

Enables use of the following operator keywords and digraphs to generate tokens:

Operator Keyword	Token
and	&&
and_eq	&=
bitand	&
bitor	
compl	~
not	!
not_eq	!=
or	
or_eq	=
xor	^
xor_eq	^=

Digraph	Token
:>	]
%:	#
%>	}
<%	{
<:	[

The default is /NOALTERNATIVE\_TOKENS when compiling with the /STANDARD=ARM, /STANDARD=MS, or /STANDARD=RELAXED option. The default is /ALTERNATIVE\_TOKENS when compiling with the /STANDARD=STRICT\_ANSI or /STANDARD=GNU option. Specifying /ALTERNATIVE\_TOKENS also defines the \_\_ALTERNATIVE\_TOKENS macro.

**Note**

This qualifier has no effect on OpenVMS x86-64.

**/ANSI\_ALIAS****/ANSI\_ALIAS (Default)****/NOANSI\_ALIAS**

Directs the compiler to assume the ANSI/ISO C aliasing rules, which gives it the freedom to generate better optimized code.

**/NOANSI\_ALIAS** specifies that any pointer can point to any object, regardless of type.

**/ANSI\_ALIAS** specifies that pointers to a type T can point to objects of the same type, ignoring type qualifiers such as `const`, `unaligned`, or `volatile`, or whether the object is signed or unsigned. Pointers to a type T can also point to structures, unions, or array members whose type follows the rules above.

The aliasing rules are further explained in the C Standard.

---

**Note**

This qualifier has no effect on OpenVMS x86-64.

---

**/ARCHITECTURE=option****/ARCHITECTURE=GENERIC (Default on Alpha and IA-64)****/ARCHITECTURE=X86="x86-64" (Default on x86-64) (x86-64 only)**

Determines the Alpha or Intel processor instruction set to be used by the compiler. The **/ARCHITECTURE** qualifier uses the same keyword options (keywords) as the **/OPTIMIZE=TUNE** qualifier.

On x86-64 systems, the compiler accepts but ignores architecture keywords from compilers on other OpenVMS targets. The x86-64 is the default architecture for CXX/Clang. Where the **/OPTIMIZE=TUNE** qualifier is primarily used by certain higher-level optimizations for instruction scheduling purposes, the **/ARCHITECTURE** qualifier determines the type of code instructions generated for the program unit being compiled. Note, that the TUNE option is ignored on x86-64 systems.

OpenVMS provides an operating system kernel that includes an instruction emulator. This emulator allows new instructions, not implemented on the host processor chip, to execute and produce correct results. Applications using emulated instructions will run correctly, but may incur significant software emulation overhead at runtime.

All Alpha processors implement a core set of instructions. Certain Alpha processor versions include additional instruction extensions.

Select one of the **/ARCHITECTURE** qualifier options shown in the following table.

Option	Usage
GENERIC	Generates code that is appropriate for all processor generations. This is the default.
HOST	Generates code for the processor generation in use on the system being used for compilation.  Running programs compiled with this option on other implementations of the Alpha architecture may encounter instruction-emulation overhead.

Option	Usage
ITANIUM2 ( <i>IA-64 only</i> )	Generates code for the Intel Itanium 2 processor family. For use on IA-64 systems only.
EV4 ( <i>Alpha only</i> )	Generates code for the 21064, 21064A, 21066, and 21068 implementations of the Alpha architecture.  Programs compiled with the EV4 option run without instruction-emulation overhead on all Alpha processors.
EV5 ( <i>Alpha only</i> )	Generates code for some 21164 chip implementations of the Alpha architecture that use only the base set of Alpha instructions (no extensions).  Programs compiled with the EV5 option will without instruction-emulation overhead on all Alpha processors.
EV56 ( <i>Alpha only</i> )	Generates code for some 21164 chip implementations that use the byte and word-manipulation instruction extensions of the Alpha architecture.  Running programs compiled with the EV56 option might incur emulation overhead on EV4 and EV5 processors, but will still run correctly on OpenVMS Version 7.1 (or higher) systems.
PCA56 ( <i>Alpha only</i> )	Generates code for the 21164PC chip implementation that uses the byte- and word-manipulation instruction extensions and multimedia instruction extensions of the Alpha architecture.  Programs compiled with the PCA56 option might incur emulation overhead on EV4, EV5, and EV56 processors, but still run correctly on OpenVMS Version 7.1 (or higher) systems.
EV6 ( <i>Alpha only</i> )	Generates code for the 21264 implementation of the Alpha architecture.
EV68 ( <i>Alpha only</i> )	Generates code for the 21264/EV68 implementation of the Alpha architecture.
EV7 ( <i>Alpha only</i> )	Generates code for the EV7 implementation of the Alpha architecture.

See also /OPTIMIZE=TUNE, which is a more typical option. Note that if /ARCHITECTURE is explicitly specified and /OPTIMIZE=TUNE is not, the tuning processor defaults to the architecture processor; for example, /ARCHITECTURE=EV6 implies /OPTIMIZE=TUNE=EV6.

#### /ASSUME

/ASSUME=(option[,...])

Controls compiler assumptions. You may select the following options:

Option	Usage
[NO]WRITABLE_STRING_LITERALS	Stores string constants in a writable psect. Otherwise, such constants are placed in a nonwriteable psect. The default is NOWRITABLE_STRING_LITERALS.
[NO]ACCURACY_SENSITIVE	Specifies whether certain code transformations that affect floating-point operations are allowed. These changes may or may not affect the accuracy of the program's results.

Option	Usage
	<p>If you specify <code>NOACCURACY_SENSITIVE</code>, the compiler is free to reorder floating-point operations based on algebraic identities (inverses, associativity, and distribution). This allows the compiler to move divide operations outside of loops, which improves performance.</p> <p>The default, <code>ACCURACY_SENSITIVE</code>, directs the compiler to use only certain scalar rules for calculations. This setting can prevent some optimization.</p>
<code>[NO]ALIGNED_OBJECTS</code>	<p>Controls an optimization for dereferencing pointers.</p> <p>Dereferencing a pointer to a longword- or quadword-aligned object is more efficient than dereferencing a pointer to a byte- or word-aligned object. Therefore, the compiler can generate more optimized code if it makes the assumption that a pointer object of an aligned pointer type does point to an aligned object.</p> <p>Because the compiler determines the alignment of the dereferenced object from the type of the pointer, and the program is allowed to compute a pointer that references an unaligned object (even though the pointer type indicates that it references an aligned object), the compiler must assume that the dereferenced object's alignment matches or exceeds the alignment indicated by the pointer type.</p> <p>The default, <code>/ASSUME=ALIGNED_OBJECTS</code>, allows the compiler to make such an assumption. With this assumption made, the compiler can generate more efficient code for pointer dereferences of aligned pointer types.</p> <p>To prevent the compiler from assuming the pointer type's alignment for objects to which it points, use the <code>/ASSUME=NOALIGNED_OBJECTS</code> qualifier. This option causes the compiler to generate longer code sequences to perform indirect load and store operations to avoid hardware alignment faults for arbitrarily aligned addresses. Although <code>/ASSUME=NOALIGNED_OBJECTS</code> might generate less efficient code than the default <code>/ASSUME=ALIGNED_OBJECTS</code> option, by avoiding hardware alignment faults, it speeds the execution of programs that reference unaligned data.</p>
<code>[NO]GLOBAL_ARRAY_NEW</code>	<p>Controls whether calls to global array new and delete are generated as specified by ANSI. Pre-ANSI global array new generated calls to operator <code>new()</code>. According to ANSI, use of global array new generates calls to operator <code>new()[]</code>. The <code>GLOBAL_ARRAY_NEW</code> option also defines the macro <code>__GLOBAL_ARRAY_NEW</code>.</p>

Option	Usage
	<p><code>GLOBAL_ARRAY_NEW</code> generates calls to operator <code>new()</code> for global array new expressions such as <code>new int[4]</code>; this is the default when compiling <code>/STANDARD=RELAXED</code>, <code>/STANDARD=STRICT_ANSI</code>, <code>/STANDARD=GNU</code>, and <code>/STANDARD=MS</code>.</p> <p><code>NOGLOBAL_ARRAY_NEW</code> generates calls to operator <code>new()</code> for global array new expressions such as <code>new int[4]</code>; and preserves compatibility with Version 5.n; this is the default when compiling <code>/STANDARD=ARM</code>.</p>
[NO]HEADER_TYPE_DEFAULT	<p>Controls whether the compiler appends a file extension to a file name. The default is <code>/ASSUME=NOHEADER_TYPE_DEFAULT</code>. To prevent the compiler from appending a file extension to files (such as STL header files that must not have file extensions) use the <code>/ASSUME=NOHEADER_TYPE_DEFAULT</code> qualifier.</p>
[NO]MATH_ERRNO	<p>Controls whether intrinsic code is generated for math functions that set the <code>errno</code> variable. The default is <code>/ASSUME=MATH_ERRNO</code>, which does not allow intrinsic code for such math functions to be generated, even if <code>/OPTIMIZE=INTRINSICS</code> is in effect. Their prototypes and call formats, however, are still checked.</p>
[NO]POINTERS_TO_GLOBALS	<p>Controls whether the compiler can safely assume that global variables have not had their addresses taken in code that is not visible to the current compilation.</p> <p>The default is <code>/ASSUME=POINTERS_TO_GLOBALS</code>, which directs the compiler to assume that global variables have had their addresses taken in separately compiled modules and that, in general, any pointer dereference could be accessing the same memory as any global variable. This is often a significant barrier to optimization.</p> <p>While the <code>/ANSI_ALIAS</code> option allows some resolution based on data type, <code>/ASSUME=POINTERS_TO_GLOBALS</code> provides significant additional resolution and improved optimization in many cases.</p> <p>The <code>/ASSUME=NOPOINTERS_TO_GLOBALS</code> option tells the compiler that any global variable accessed through a pointer in the compilation must have had its address taken within that compilation. The compiler can see any code that takes the address of an extern variable. If it does not see the address of the variable being taken, the compiler can assume that no pointer points to the variable.</p> <p>Note that <code>/ASSUME=NOPOINTERS_TO_GLOBALS</code> does not tell the compiler that the compilation never uses pointers to access global variables.</p>

Option	Usage
	Also note that on IA-64 systems, the NOPOINTERS_TO_GLOBALS option is ignored and should not cause any behavior changes.
[NO]STDNEW	<p>Controls whether calls are generated to the ANSI or pre-ANSI implementation of the operator new(). On memory allocation failure, the ANSI implementation throws <code>std::bad_alloc</code>, while the pre-ANSI implementation returns 0.</p> <p>/ASSUME=STDNEW generates calls to the ANSI new() implementation; this is the default when compiling with /STANDARD=RELAXED, /STANDARD= STRICT_ANSI, and /STANDARD=GNU.</p> <p>/ASSUME=NOSTDNEW generates calls to the pre-ANSI new() implementation; this is the default when compiling with /STANDARD=ARM and /STANDARD=MS.</p>
[NO]TRUSTED_SHORT_ALIGNMENT	<p>Allows the compiler additional assumptions about the alignment of short types that, although thought to be naturally aligned, might cross a quadword boundary.</p> <p>The TRUSTED_SHORT_ALIGNMENT option indicates that the compiler should assume any datatype accessed through a pointer is naturally aligned. This generates the fastest code, but can silently generate the wrong results when an unaligned short object crosses a quadword boundary.</p> <p>Note that on IA-64 systems, the TRUSTED_SHORT_ALIGNMENT option is ignored and should not cause any behavior changes.</p> <p>The NOTRUSTED_SHORT_ALIGNMENT tells the compiler that short objects might not be naturally aligned. The compiler generates slightly larger (and slower) code that gives the correct result, regardless of the actual alignment of the data. This is the default.</p> <p>Note that the NOTRUSTED_SHORT_ALIGNMENT option does not override the __unaligned type qualifier or the /ASSUME=NOALIGNED_OBJECTS option.</p>
[NO]WHOLE_PROGRAM	Tells the compiler that except for well-behaved library routines, the whole program consists only of the single object module being produced by this compilation. The optimizations enabled by /ASSUME=WHOLE_PROGRAM include all those enabled by /ASSUME=NOPOINTERS_TO_GLOBALS and possibly other optimizations.

Option	Usage
	Note that on IA-64 systems, the <code>WHOLE_PROGRAM</code> option is ignored and should not cause any behavior changes.  The default is <code>/ASSUME=NOWHOLE_PROGRAM</code> .

## Note

This qualifier has no effect on OpenVMS x86-64.

## **/CHECK**

**/CHECK=[([NO]UNINITIALIZED \_VARIABLES)]** (*Alpha only*)

**/NOCHECK** (Default)

Use this qualifier as a debugging aid.

Use `/CHECK=UNINITIALIZED_VARIABLES` to initialize all automatic variables to the value `0x7ff580057ff58005`. This value is a floating NaN and, if used, causes a floating-point trap. If used as a pointer, this value is likely to cause an ACCVIO.

Note that on IA-64 systems, `/CHECK=UNINITIALIZED_VARIABLES` emits a warning and is ignored.

## Note

This qualifier has no effect on OpenVMS x86-64.

## **/CLANG=(quoted\_string[,...])** (*x86-64 only*)

Passes provided strings to the Clang driver as UNIX-style options.

DCL converts all input to uppercase unless it is enclosed in quotation mark so it's important to specify the options in double quotes and separated by commas.

Example:

```
$ CXX /CLANG=("-Wall", "-D__macro1", "-D__MACRO2") foo.cxx
```

## **/COMMENTS**

**/COMMENTS[=option]**

**/COMMENTS=SPACE** (Default)

**/NOCOMMENTS**

Specifies whether comments appear in preprocessor output files. If comments do not appear, this qualifier specifies what replaces them. The options are:

Option	Usage
<code>AS_IS</code>	Specifies that the comment appear in the output file. This is the default if you use the <code>/COMMENTS</code> qualifier without specifying an option.

Option	Usage
SPACE	Specifies that a single space replaces the comment in the output file. This is the default if you do not specify the /COMMENTS qualifier at all.

Specifying /NOCOMMENTS tells the preprocessor that nothing replaces the comment in the output file. This may result in inadvertent token pasting.

The preprocessor may replace a comment at the end of a line or replace a line by itself with nothing, even if you specify /COMMENTS=SPACE. Specifying /COMMENTS=SPACE cannot change the meaning of the program.

## **/DEBUG**

**/DEBUG[=(option[,...])]**

**/DEBUG=(TRACEBACK, NOSYMBOLS) (Default)**

**/NODEBUG**

Requests that information be included in the object module for use with the OpenVMS Debugger. You can select the following options:

Option	Usage
ALL	Includes all possible debugging information. /DEBUG=ALL is equivalent to /DEBUG=(TRACEBACK,SYMBOLS), which on IA-64 systems is equivalent to /DEBUG=(TRACEBACK, SYMBOLS=NOBRIEF).
NONE	Excludes all debugging information. This option is equivalent to specifying /NODEBUG, which is equivalent to /DEBUG=(NOTRACEBACK,NOSYMBOLS).
NOSYMBOLS	Turns off symbol generation
SYMBOLS	Generates symbol-table records. On IA-64 systems, /DEBUG= SYMBOLS is equivalent to /DEBUG=SYMBOLS=BRIEF. On Alpha systems, /DEBUG=SYMBOLS is effectively equivalent to /DEBUG=NOBRIEF.
SYMBOLS=BRIEF ( <i>IA-64 only</i> )	Generates debug information with unreferenced labels and types pruned out to produce smaller object sizes. On Alpha systems, BRIEF is ignored.
SYMBOLS=NOBRIEF ( <i>IA-64 only</i> )	Generates complete debug information. On Alpha systems, the NOBRIEF keyword is ignored, but you still get complete debug information.
NOTRACEBACK	Excludes traceback records. This option is equivalent to specifying /NODEBUG and is used to avoid generating extraneous information from thoroughly debugged program modules.
TRACEBACK	Includes only traceback records. This option is the default if you do not specify the /DEBUG qualifier on the command line.

On Alpha and x86-64 systems, /DEBUG is equivalent to /DEBUG=(TRACEBACK,SYMBOLS).

On IA-64 systems, /DEBUG is equivalent to /DEBUG=(TRACEBACK,SYMBOLS), which is equivalent to /DEBUG=(TRACEBACK,SYMBOLS=BRIEF).



**/DEFINE****/DEFINE=(identifier[=definition][,...])****/NODEFINE (Default)**

Performs the same function as the `#define` preprocessor directive. That is, `/DEFINE` defines a token string or macro to be substituted for every occurrence of a given identifier in the program.

DCL converts all input to uppercase unless it is enclosed in quotation marks.

The simplest form of a `/DEFINE` definition is as follows: `/DEFINE=true`

This results in a definition like the one that would result from the following definition: `#define TRUE 1`

When more than one `/DEFINE` is present on the CXX command line or in a single compilation unit, only the last `/DEFINE` is used.

When both `/DEFINE` and `/UNDEFINE` are present on a command line, `/DEFINE` is evaluated before `/UNDEFINE`

**/DEFINE=\_\_FORCE\_INSTANTIATIONS (Alpha only)****/NODEFINE=\_\_FORCE\_INSTANTIATIONS (Default)**

Forces the standard library template pre-instantiations to be created in the user's repository. Normally these instantiations are suppressed because the library already contains them.

On IA-64 systems, defining `__FORCE_INSTANTIATIONS` has no effect.

**/DEFINE=\_\_[NO\_]USE\_STD\_Iostream (Alpha and IA-64 only)****/NODEFINE=\_\_NO\_USE\_STD\_Iostream (Default)**

Use or do not use the standard iostreams. Specifying `/DEFINE=__USE_STD_Iostream` forces the inclusion of the ANSI standard version of the iostream header file. This is the default in `STRICT_ANSI` mode. Otherwise, the pre-standard AT&T-compatible version of iostreams is used.

**/DIAGNOSTICS****/DIAGNOSTICS[=file-spec]****/NODIAGNOSTICS (Default)**

Creates a file containing compiler diagnostic messages. The default file extension for a diagnostics file is `.DIA`. The diagnostics file is used with the VSI Language-Sensitive Editor (LSE). To display a diagnostics file, enter the command `REVIEW/FILE=file-spec` while in LSE.

---

**Note**

This qualifier has no effect on OpenVMS x86-64.

---

**/DISTINGUISH\_NESTED\_ENUMS****/NODISTINGUISH\_NESTED\_ENUMS (Default)**

Causes the compiler, when forming a mangled name, to include the name of any enclosing classes within which an enum is nested, thereby preventing different functions from receiving the same mangled name.

This qualifier has no meaning on IA-64 systems because it modifies the behavior of programs compiled with /MODEL=ARM, and that model is not supported on IA-64 systems.

---

**Note**

This qualifier has no effect on OpenVMS x86-64.

---

**/ENDIAN**

**/ENDIAN={BIG | LITTLE}**

**/ENDIAN=LITTLE (Default)**

Controls whether big or little endian ordering of bytes is carried out in character constants.

---

**Note**

This qualifier has no effect on OpenVMS x86-64.

---

**/ERROR\_LIMIT**

**/ERROR\_LIMIT[=number]**

**/ERROR\_LIMIT=30 (Default on Alpha and IA-64)**

**/ERROR\_LIMIT=20 (Default on x86-64)**

**/NOERROR\_LIMIT**

Limits the number of error-level diagnostic messages that are acceptable during program compilation. Compilation terminates when the limit (number) is exceeded. /NOERROR\_LIMIT specifies that there is no limit on error messages.

On Alpha and IA-64 systems, the default is /ERROR\_LIMIT=30, which specifies that compilation terminates after issuing 30 error messages.

On x86-64 systems, the default is /ERROR\_LIMIT=20, which specifies that compilation terminates after issuing 20 error messages.

**/EXCEPTIONS**

**/EXCEPTIONS=CLEANUP (Default on Alpha and IA-64)**

**/EXCEPTIONS=NOCLEANUP (*Alpha only*)**

**/EXCEPTIONS=EXPLICIT (Default on Alpha and IA-64)**

**/EXCEPTIONS=IMPLICIT (*Alpha only*)**

**/NOEXCEPTIONS**

Controls whether support for C++ exceptions is enabled or disabled. C++ exceptions are enabled by default (equivalent to /EXCEPTIONS=CLEANUP). When C++ exceptions are enabled, the compiler generates code for throw expressions, try blocks, and catch statements. The compiler also generates special code for main programs so that the terminate() routine is called for unhandled exceptions.

You can select from the following options. Note that, on x86-64 systems, the following options are allowed but are ignored:

CLEANUP	Generate cleanup code for automatic objects. When an exception is handled at run-time and control passes from a throw-point to a handler,
---------	---

	call the destructors for all automatic objects that were constructed because the try-block containing the handler was entered.
NOCLEANUP ( <i>Alpha only</i> )	<p>Do not generate cleanup code. Using this option can reduce the size of your executable when you want to throw and handle exceptions and cleanup of automatic objects during exception processing is not important for your application.</p> <p>The NOCLEANUP option is ignored on IA-64 systems.</p>
EXPLICIT	Tells the compiler to assume the standard C++ rules about exceptions. Catch clauses can catch only those exceptions resulting from the evaluation of a throw expression within the body of the catch clause's try block or from within a procedure called from within the catch clause's try block.
IMPLICIT ( <i>Alpha only</i> )	<p>On Alpha systems, tells the compiler that an exception might be thrown at any time the program is executing code within the body of the try block. These exceptions might be the result of a throw expression, hardware errors, or software errors (such as dereferencing an invalid pointer).</p> <p>Specifying /EXCEPTIONS=IMPLICIT seriously interferes with the compiler's ability to optimize code. When the compiler optimizes a function, it must ensure that the values of all variables after an exception is caught remain the same as they were at the point where the exception was throw. The optimizer is therefore limited in its ability to rearrange stores and expressions that might cause an exception to be thrown.</p> <p>With /EXCEPTIONS=EXPLICIT, this is not a serious restriction, because the compiler cannot rearrange stores and expressions around the code that explicitly raises an exception. In implicit exception mode, however, almost any code has the potential to cause an exception to be thrown, thereby dramatically reducing the optimizer's ability to rearrange code.</p> <p>Also, if the compiler can determine that no throw expressions occur within a try block, it can eliminate the exception handling overhead the try block introduces, including all code within the catch clauses associated with the try block. Because no exceptions can occur during the execution of the code within the try block, no code within the catch clauses can ever be executed. The compiler cannot do this with /EXCEPTIONS=IMPLICIT.</p> <p>Use /EXCEPTIONS=IMPLICIT if your program converts signals to C++ exceptions by calling <code>cxxl\$set_condition(cxx_exception)</code>. Failure to do so may result in your code not catching the exceptions produced by signals.</p>

For example, consider the following routine:

```
void f(int *p) {
    try {
        *p = 2;
    } catch (...) {
        ...
    }
}
```

Failure to compile the routine with /EXCEPTIONS=IMPLICIT may result in a failure to catch the exception generated by the SIGBUS signal that occurs if `p` is 0. This is because the compiler sees

that there are no throws nor procedure calls within `f` and therefore optimizes away the try block leaving:

```
void f(int *p) {  
    *p = 2;  
}
```

Except for those OpenVMS conditions that result in the delivery of signals, if you raise a condition explicitly using a mechanism such as `LIB$SIGNAL`, you may use `/EXCEPTIONS=EXPLICIT`.

The `/NOEXCEPTIONS` qualifier disables C++ exceptions as follows:

1. The compiler issues errors for throw expressions, try blocks, and catch statements, but might generate code for these constructs.
2. On Alpha systems, the compiler does not generate cleanup code for automatic objects.
3. The compiler does not generate special code for main programs so that the `terminate()` function is called for unhandled exceptions.

The `/EXCEPTIONS` qualifier defines the macro `__EXCEPTIONS`.

**`/EXPORT_SYMBOLS=(OPTIONS_FILE=<name> [,EXCLUDE=<list of images>]  
[,export_option] [,NOTEMPLATES]) (IA-64 only)`**

Creating OpenVMS shareable images that contain C++ code has long been a problem for users. When building a shareable image, you must specify a list of exported global symbols. For C++ code, determining this list can be very difficult for the following reasons:

- Required C++ name mangling makes it difficult to know the name of the external symbol created for a C++ name.
- OpenVMS CRC encoding (to 31 characters) further complicates mapping source names to object names.
- Certain C++ constructs require compiler-generated names to be created and exported.

To help solve the problem, the VSI C++ compiler provides the `/EXPORT_SYMBOLS` qualifier and `__declspec(dllexport)` declaration modifier.

The default file extension for the `OPTIONS_FILE <name>` is `.OPT`.

If the file exists, the compiler appends to it. If the file does not exist, the compiler creates it.

The output for the compilation is:

```
!  
! Entries added for <module>  
!  
<symbol vector>  
<symbol vector>  
.  
.  
.
```

The output file is suitable input to a linker options file that can be used to build a shareable image containing the compiled object.

The format of each `<symbol vector>` is:

---

```
SYMBOL_VECTOR=(<global name>={DATA | PROCEDURE}) ! <comment field>
```

The `<comment field>` format is:

```
<unmangled name> [<promoted static flag>] [<class information>]
```

The `<promoted static flag>` is one of the following:

- \*PSDM\* - for promoted static data members
- \*PTSDM\* - for promoted template static data members

The `<promoted static flag>` is output whenever the symbol is a promoted local static or a promoted template static data member. This is important because these variables, while declared static, actually become global symbols when compiled.

The `<class information>` field is present if the symbol is a member of a class. It contains the name of the class.

---

## Note

- When `/EXPORT_SYMBOLS` is specified, an object file must also be generated. So `/EXPORT_SYMBOLS` cannot be used with `/NOOBJ`, `/PREPROCESS_ONLY`, or any other qualifier that prevents the creation of an object file.
- When the options file already exists, the compiler reads all the symbols that are listed there. If the current compilation also defines one of those symbols, that symbol will not be added to the options file. This is necessary to prevent SYMVALRDEF warnings from the linker.
- When the compiler reads the existing file, it treats `SYMBOL_VECTOR` directives that are in comments (of the form `!SYMBOL_VECTOR...`) as if they were not commented. In this way, if a user does not want to export a symbol, placing it in comments will prevent the compiler from emitting a directive for that symbol when it compiles other sources that might also define the symbol.
- The symbols placed in the options file are a subset of the symbols defined in the output object file. The `export_option` value controls exactly which symbols are placed there. There are three choices:

Export_option Value	Usage
ALL	Place all symbols suitable for placement in a sharable image into the options file. The compiler knows that certain symbols are not suited for placement in a shareable image and excludes them from the options file. Some examples are certain compiler-generated constructor/destructor jackets and symbols in the unnamed namespace.
EXPLICIT	Place only those symbols marked with the <code>__declspec(dllexport)</code> declaration modifier into the options file.
AUTOMATIC(D)	If the compiler processes a <code>__declspec(dllexport)</code> , then act as if EXPLICIT was specified. If the compiler does not process a <code>__declspec(dllexport)</code> , then act as if ALL was specified.

- The EXCLUDE option of the `/EXPORT_SYMBOLS` qualifier can be used to specify a list of shareable images. The compiler searches these images for any symbols that it might want to

place in the output options file. If it finds the symbol in the image, then that symbol will not be put into the options file.

- The `NOTEMPLATES` option can be used to control the emission of symbols associated with template instantiations. Specifying this option causes the compiler to suppress symbols created by template instantiation. This includes instantiations of class templates, its data members and member functions, and instantiations of function templates. This option could be used to avoid multiple definition diagnostics from the linker if multiple sharable images might be instantiating (and exporting) the same template symbols. Symbols marked with `__declspec(dllexport)` still get exported. This option has no effect on symbols from template specializations. Note that while this option might make the sharable images smaller by not exporting the template symbols, the executable image that links with these sharable images might be larger because it will contain the instantiated template symbols.
- 

Because shareable images almost always contain a number of objects, the commands for creating the options file the first time might be:

```
$ DELETE options_file.OPT;*
$ CXX SOURCE1/EXPORT_SYMBOLS=OPTIONS_FILE=options_file
$ CXX SOURCE2/EXPORT_SYMBOLS=OPTIONS_FILE=options_file
$ CXX SOURCE3/EXPORT_SYMBOLS=OPTIONS_FILE=options_file
.
.
.
$ CXX SOURCEn/EXPORT_SYMBOLS=OPTIONS_FILE=options_file
```

Where `SOURCE1` - `SOURCEn` are the sources for the shareable. After the compilations, the `options_file.OPT` will contain correct symbol vector information for the shareable.

The first time this options file is created, it can be considered a candidate options file. It contains all the symbol vector entries for all the C++ globals that make sense to export from the C++ language point of view. A user can then edit this file to exclude (by commenting out) entries that should not be exported, based on the design of the library.

Once an options file is created, it should be maintained for input to subsequent compilations. In this way, any new symbols caused by a change in the source will be added to the end of the compilation. Any existing symbols will not be added, as described in the `NOTES` section above. This technique ensures that the order of symbols remains unchanged, and that future shared libraries are compatible with existing ones.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

### **/EXTERN\_MODEL**

**/EXTERN\_MODEL=option**

**/EXTERN\_MODEL=RELAXED\_REFDEF (Default)**

In conjunction with the `/SHARE_GLOBALS` qualifier, controls the initial extern model of the compiler. Conceptually, the compiler behaves as if the first line of the program being compiled was a `#pragma extern_model` directive with the model and psect name, if any, specified by the `/EXTERN_MODEL` qualifier and with the `SHR` or `NOSHR` keyword specified by the

/SHARE\_GLOBALS qualifier. Note that, on x86-64 systems, the /SHARE\_GLOBALS qualifier has no effect and is therefore ignored.

For example, assume the command line contains the following qualifier:

```
/EXTERN_MODEL=STRICT_REFDEF="MYDATA" /NOSHARE
```

The compiler acts as if the program began with the following line:

```
#pragma extern_model strict_refdef "MYDATA" noshr
```

For more information on the various models, see *Section 2.1.1.4, "#pragma extern\_model Directive"*.

The /EXTERN\_MODEL qualifier takes the following options, which have the same meaning as for the #pragma extern\_model directive:

```
COMMON_BLOCK
RELAXED_REFDEF
STRICT_REFDEF=["NAME"]
GLOBALVALUE
```

The default is RELAXED\_REFDEF.

Use of an /EXTERN\_MODEL value other than RELAXED\_REFDEF should be limited to compilations that either declare only POD (Plain Old Data) objects, or that carefully use the extern\_model (and/or environment) #pragma directives to ensure that declarations of non-POD objects appear only in source that is subject to the default extern\_model of relaxed\_refdef.

**/FIRST\_INCLUDE**  
**/FIRST\_INCLUDE=(file[,...])**  
**/NOFIRST\_INCLUDE (Default)**

Includes the specified files before any source files. On Alpha and IA-64 systems, this qualifier corresponds to the UNIX `-FI` switch. On x86-64 systems, this qualifier corresponds to the Clang's `-include` option.

When /FIRST\_INCLUDE=*file* is specified, *file* is included in the source as if the line before the first line of the source were:

```
#include "file"
```

If more than one file is specified, the files are included in their order of appearance on the command line.

This qualifier is useful if you have command lines to pass to the C compiler that are exceeding the DCL command-line length limit. Using the /FIRST\_INCLUDE qualifier can help solve this problem by replacing lengthy /DEFINE and /WARNINGS qualifiers with #define and #pragma message preprocessor directives placed in a /FIRST\_INCLUDE file.

The default is /NOFIRST\_INCLUDE.

**/FLOAT**  
**/FLOAT=option**  
**/FLOAT=G\_FLOAT (Default on Alpha) (Alpha only)**  
**/FLOAT=IEEE\_FLOAT (Default on IA-64) (IA-64 only)**

Controls the format of floating-point variables. The options are:

Option	Usage
D_FLOAT	double variables are represented in VAX D_floating format. float variables are represented in VAX F_floating format. The __D_FLOAT macro is predefined.
G_FLOAT	double variables are represented in VAX G_floating format. float variables are represented in VAX F_floating format. The __G_FLOAT macro is predefined.
IEEE_FLOAT	float and double variables are represented in IEEE floating-point format (S_float and T_float, respectively). The __IEEE_FLOAT macro is predefined. Use the /IEEE_MODE qualifier for controlling the handling of IEEE exceptional values.

On Alpha systems, the default is /FLOAT=G\_FLOAT.

On IA-64 systems, the default is /FLOAT=IEEE\_FLOAT.

On x86-64 systems, the default is IEEE floating-point format with no ability to use VAX floating formats.

See *Section 4.1.6, "Floating Point"* for additional information on floating-point representation on IA-64 and Alpha systems.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

## /GRANULARITY

**/GRANULARITY=option**

**/GRANULARITY=QUADWORD (Default)**

Controls the size of shared data in memory that can be safely accessed from different threads. The possible size values are BYTE, LONGWORD, and QUADWORD.

Specifying BYTE allows single bytes to be accessed from different threads sharing data in memory without corrupting surrounding bytes. This option will slow runtime performance.

Specifying LONGWORD allows naturally aligned 4-byte longwords to be accessed safely from different threads sharing data in memory. Accessing data items of 3 bytes or less, or unaligned data, may result in data items written from multiple threads being inconsistently updated.

Specifying QUADWORD allows naturally aligned 8-byte quadwords to be accessed safely from different threads sharing data in memory. Accessing data items of 7 bytes or less, or unaligned data, might result in data items written from multiple threads being inconsistently updated. This is the default.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---



**/IEEE\_MODE**

**/IEEE\_MODE=option**

**/IEEE\_MODE=FAST (Default on Alpha) (*Alpha only*)**

**/IEEE\_MODE=DENORM\_RESULTS (Default on IA-64) (*IA-64 only*)**

Selects the IEEE floating-point mode to be used if the /FLOAT=IEEE\_FLOAT qualifier is specified. The options are:

Option	Usage
FAST	During program execution, only finite values (no infinities, NaNs, or denorms) are created. Underflows and denormal values are flushed to zero. Exceptional conditions, such as floating-point overflow, divide-by-zero, or use of an IEEE exceptional operand are fatal.
UNDERFLOW_TO_ZERO	Generate infinities and NaNs. Flush denormalized results and underflow to zero without exceptions.
DENORM_RESULTS	Same as the UNDERFLOW_TO_ZERO option, except that denorms are generated.
INEXACT	Same as the DENORM_RESULTS option, except that inexact values are trapped. This is the slowest mode, and is not appropriate for any sort of general-purpose computations.

On Alpha systems, the default is /IEEE\_MODE=FAST.

On IA-64 systems, the default is /IEEE\_MODE=DENORM\_RESULTS.

The INFINITY and NAN macros defined in `<math.h>` are available to programs compiled with /FLOAT=IEEE and /IEEE\_MODE={*anything other than FAST*}.

On Alpha systems, the /IEEE\_MODE qualifier generally has its greatest effect on the generated code of a compilation. When calls are made between functions compiled with different /IEEE\_MODE qualifiers, each function produces the /IEEE\_MODE behavior with which it was compiled.

On IA-64 systems, the /IEEE\_MODE qualifier primarily affects only the setting of a hardware register at program startup. In general, the /IEEE\_MODE behavior for a given function is controlled by the /IEEE\_MODE option specified on the compilation that produced the main program: the startup code for the main program sets the hardware register according the command-line qualifiers used to compile the main program.

When applied to a compilation that does not contain a main program, the /IEEE\_MODE qualifier does have some effect: it might affect the evaluation of floating-point constant expressions, and it is used to set the EXCEPTION\_MODE used by the math library for calls from that compilation. But the qualifier has no effect on the exceptional behavior of floating-point calculations generated as inline code for that compilation. Therefore, if floating-point exceptional behavior is important to an application, all of its compilations, including the one containing the main program, should be compiled with the same /IEEE\_MODE setting.

Even on Alpha systems, the particular setting of /IEEE\_MODE=UNDERFLOW\_TO\_ZERO has this characteristic: its primary effect requires the setting of a runtime status register, and so it needs to be specified on the compilation containing the main program in order to be effective in other compilations.

Also see the /FLOAT qualifier.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

### **/IMPLICIT\_INCLUDE**

#### **/IMPLICIT\_INCLUDE (Default)**

### **/NOIMPLICIT\_INCLUDE**

**/IMPLICIT\_INCLUDE** enables inclusion of source files as a method of finding definitions of template entities. By default it is enabled for normal compilation, and disabled for preprocessing only. The search rules for finding template definition files is the same as for include files.

**/NOIMPLICIT\_INCLUDE** disables inclusion of source files as a method of finding definitions of template entities. You might want to use this option in conjunction with the **/STANDARD=MS** command line option, to match more closely the behavior on Microsoft C++.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

### **/INCLUDE\_DIRECTORY**

#### **/INCLUDE\_DIRECTORY=(place[,...])**

### **/NOINCLUDE\_DIRECTORY (Default)**

Provides an additional level of search for user-defined include files. Each *pathname* argument can be either a logical name or a legal UNIX style directory in a quoted string. The default is **/NOINCLUDE\_DIRECTORY**.

On Alpha and IA-64 systems, the **/INCLUDE\_DIRECTORY** qualifier provides functionality similar to the **-I** option of the **cxx** command on UNIX systems. On x86-64 systems, this qualifier provides functionality similar to the **-I** option of the Clang command.

This qualifier allows you to specify additional locations to search for files to include. Putting an empty string in the specification prevents the compiler from searching any of the locations it normally searches but directs it to search *only* in locations you identify explicitly on the command line with the **/INCLUDE\_DIRECTORY** And **/LIBRARY** qualifiers (or by way of the specification of the primary source file, depending on the **/NESTED\_INCLUDE\_DIRECTORY** qualifier).

The basic order for searching depends on the form of the header name (after macro expansion), with additional aspects controlled by other command line qualifiers as well as the presence or absence of logical name definitions. The valid possibilities for names are as follows:

- Enclosed in quotes. For example: "stdio.h"
- Enclosed in angle brackets. For example: <stdio.h>

Unless otherwise defined, searching a location means that the compiler uses the string specifying the location as the default file specification in a call to an RMS system service (that is, a **\$SEARCH/\$PARSE**) with a primary file specification consisting of the name in the **#include** (without enclosing delimiters). The search terminates successfully as soon as a file can be opened for reading.

---

Specifying a null string in the `/INCLUDE` qualifier causes the compiler to do a non-standard search. This search path is as follows:

1. **Alpha and IA-64:** The current directory (quoted form only).  
**x86-64:** The directory of the primary input file.
2. Any directories specified in the `/INCLUDE` qualifier.
3. **Alpha and IA-64:** The directory of the primary input file.
4. Text libraries specified on the command line using `/LIBRARY`.

On Alpha and IA-64 for standard searches, the search order is as follows:

1. Search the current directory (directory of the source being processed). If angle-bracket form, search only if no directories are specified with `/INCLUDE_DIRECTORY`.
2. Search the locations specified in the `/INCLUDE_DIRECTORY` qualifier (if any).
3. If `CXX$SYSTEM_INCLUDE` is defined as a logical name, search `CXX$SYSTEM_INCLUDE:.HXX` or just `CXX$SYSTEM_INCLUDE:.`, depending on the qualifier `/ASSUME=NOHEADER_TYPE_DEFAULT`. If nothing is found, go to step 6.
4. If `CXX$LIBRARY_INCLUDE` is defined as a logical name, `CXX$LIBRARY_INCLUDE:.HXX` or `CXX$LIBRARY_INCLUDE:.`, depending on the qualifier `/ASSUME=NOHEADER_TYPE_DEFAULT`. If nothing is found, go to step 6.
5. If `/ASSUME=HEADER_TYPE_DEFAULT` is not specified, search the default list of locations for plain-text copies of compiler header files as follows:

```
SYS$COMMON:[CXX$LIB.INCLUDE.CXXL$ANSI_DEF]
SYS$COMMON:[CXX$LIB.INCLUDE.DECC$RTLDEF_HXX].HXX
SYS$COMMON:[DECC$LIB.INCLUDE.DECC$RTLDEF].H
SYS$COMMON:[DECC$LIB.INCLUDE.SYS$STARLET_C].H
```

If `/ASSUME=HEADER_TYPE_DEFAULT` is specified, search the default list of locations for plain-text copies of compiler header files as follows:

```
SYS$COMMON:[CXX$LIB.INCLUDE.DECC$RTLDEF_HXX].HXX
SYS$COMMON:[DECC$LIB.INCLUDE.DECC$RTLDEF].H
SYS$COMMON:[DECC$LIB.INCLUDE.SYS$STARLET_C].H
SYS$COMMON:[CXX$LIB.INCLUDE.CXXL$ANSI_DEF]
```

6. Search the directory of the primary input file.
7. If quoted form, and `CXX$USER_INCLUDE` is defined as a logical name, search `CXX$USER_INCLUDE:.HXX` or `CXX$USER_INCLUDE:.`, depending on the `/ASSUME=NOHEADER_TYPE_DEFAULT` qualifier.
8. Search the text libraries. Extract the simple file name and file type from the `#include` specification, and use them to determine a module name for each text library. There are three forms of module names used by the compiler:
  - a. type stripped:

The file type will be removed from the include file specification to form a library module name. Examples:

#include "foo.h"	Module name "FOO"
#include "foo"	Module name "FOO"
#include "foo"	Module name "FOO"

b. type required:

The file type must be a part of the file name. Examples:

#include "foo.h"	Module name "FOO.H"
#include "foo"	Module name "FOO."
#include "foo"	Module name "FOO."

c. type optional:

First an attempt is made to find a module with the type included in the module name. If this is unsuccessful, an attempt is made with the type stripped from the module name. If this is unsuccessful, the search moves on to the next library.

If /ASSUME=HEADER\_TYPE\_DEFAULT is specified, the following text libraries are searched in this order:

Libraries specified on the command line with the /LIBRARY qualifier (all files, type stripped)  
CXX\$TEXT\_LIBRARY (all files, type stripped)  
DECC\$RTLDEF (H files and unspecified files, type stripped)  
SYS\$STARLET\_C (all files, type stripped)  
CXXL\$ANSI\_DEF (unspecified files, type stripped)

Otherwise, these text libraries are searched in this order:

Libraries specified on the command line with the /LIBRARY qualifier (all files, type optional)  
CXX\$TEXT\_LIBRARY (all files, type optional)  
CXXL\$ANSI\_DEF (all files, type required)  
DECC\$RTLDEF (H files and unspecified files, type stripped)  
SYS\$STARLET\_C (all files, type stripped)

Two text library search examples (stop when something is found):

## Example 1

```
#include "foo"
```

- a. For each library specified via the `/LIBRARY` qualifier:
  - Look for "FOO."
  - Look for "FOO"
- b. Look for "FOO." in `CXX$TEXT_LIBRARY`
- c. Look for "FOO" in `CXX$TEXT_LIBRARY`
- d. Look for "FOO." in `CXXL$ANSI_DEF` (Do not look for "FOO" because the type is required as part of the module name)
- e. Look for "FOO" in `DECC$RTLDEF` (not "FOO." because the type must not be part of the module name)
- f. Look for "FOO" in `SY$STARLET_C` (not "FOO." because the type must not be part of the module name)

## Example 2

```
#include "foo.h"
```

- a. For each library specified via the `/LIBRARY` qualifier:
  - Look for "FOO.H"
  - Look for "FOO"
- b. Look for "FOO.H" in `CXX$TEXT_LIBRARY`
- c. Look for "FOO" in `CXX$TEXT_LIBRARY`
- d. Look for "FOO.H" in `CXXL$ANSI_DEF` (Do not look for "FOO" because the type is required as part of the module name)
- e. Look for "FOO" in `DECC$RTLDEF` (not "FOO.H" because the type must not be part of the module name)
- f. Look for "FOO" in `SY$STARLET_C` (not "FOO.H" because the type must not be part of the module name)
- g. If neither `CXX$LIBRARY_INCLUDE` nor `CXX$SYSTEM_INCLUDE` is defined as a logical name, then search `SY$LIBRARY:.HXX`.

On x86-64 for standard searches, the search order is as follows:

1. Search the directory of the primary input file.
2. Search the locations specified in the `/INCLUDE_DIRECTORY` qualifier (if any).

3. If `CXX$SYSTEM_INCLUDE` is defined as a logical name, search `CXX$SYSTEM_INCLUDE:.HXX` or just `CXX$SYSTEM_INCLUDE:.`
4. If `CXX$LIBRARY_INCLUDE` is defined as a logical name, `CXX$LIBRARY_INCLUDE:.HXX` or `CXX$LIBRARY_INCLUDE:.`
5. If quoted form, and `CXX$USER_INCLUDE` is defined as a logical name, search `CXX$USER_INCLUDE:.HXX` or `CXX$USER_INCLUDE:.`
6. Search the text libraries. Extract the simple file name and file type from the **#include** specification, and use them to determine a module name for each text library. There are three forms of module names used by the compiler:

a. type stripped:

The file type will be removed from the include file specification to form a library module name. Examples:

<code>#include "foo.h"</code>	Module name "FOO"
<code>#include "foo"</code>	Module name "FOO"
<code>#include "foo"</code>	Module name "FOO"

b. type required:

The file type must be a part of the file name. Examples:

<code>#include "foo.h"</code>	Module name "FOO.H"
<code>#include "foo"</code>	Module name "FOO."
<code>#include "foo"</code>	Module name "FOO."

c. type optional:

First an attempt is made to find a module with the type included in the module name. If this is unsuccessful, an attempt is made with the type stripped from the module name. If this is unsuccessful, the search moves on to the next library.

Two text library search examples (stop when something is found):

## Example 1

```
#include "foo"
```

a. For each library specified via the `/LIBRARY` qualifier:

- Look for "FOO."
- Look for "FOO"

b. Look for "FOO." in `CXX$TEXT_LIBRARY`

c. Look for "FOO" in `CXX$TEXT_LIBRARY`

d. Look for "FOO" in `DECC$RTLDEF` (not "FOO." because the type must not be part of the module name)

- e. Look for "FOO" in SYS\$STARLET\_C (not "FOO." because the type must not be part of the module name)

## Example 2

```
#include "foo.h"
```

- a. For each library specified via the /LIBRARY qualifier:
  - Look for "FOO.H"
  - Look for "FOO"
- b. Look for "FOO.H" in CXX\$TEXT\_LIBRARY
- c. Look for "FOO" in CXX\$TEXT\_LIBRARY
- d. Look for "FOO" in DECC\$RTLDEF (not "FOO.H" because the type must not be part of the module name)
- e. Look for "FOO" in SYS\$STARLET\_C (not "FOO.H" because the type must not be part of the module name)
- f. If neither CXX\$LIBRARY\_INCLUDE nor CXX\$SYSTEM\_INCLUDE is defined as a logical name, then search SYS\$LIBRARY:.HXX.

### **/L\_DOUBLE\_SIZE**

#### **/L\_DOUBLE\_SIZE=option**

#### **/L\_DOUBLE\_SIZE=128 (Default)**

Determines how the compiler interprets the long double type. The qualifier options are 64 and 128. The default value is 128.

Specifying /L\_DOUBLE\_SIZE=64 treats all long double references as G\_FLOAT, D\_FLOAT, or T\_FLOAT, depending on the value of the /FLOAT qualifier. Specifying /L\_DOUBLE\_SIZE=64 also defines the macro \_\_X\_FLOAT=0.

---

### **Note**

The /L\_DOUBLE\_SIZE=64 option is not available on IA-64 systems. If it is specified, the compiler issues a warning message and uses /L\_DOUBLE\_SIZE=128.

---

On Alpha and IA-64 systems, specifying /L\_DOUBLE\_SIZE=128 treats all long double references as X\_FLOAT. The /L\_DOUBLE\_SIZE=128 option also defines the macro \_\_X\_FLOAT=1. This is the default.

### **/LIBRARY**

Indicates that the associated input file is a text library containing source text modules specified in #include directives. The compiler searches the specified library for all #include module names that are not enclosed in angle brackets or quotation marks. The name of the library must be concatenated with the file specification using a plus sign. For example:

```
CXX DATAB/LIBRARY+APPLICATION
```

**/LINE\_DIRECTIVES****/LINE\_DIRECTIVES (Default)****/NOLINE\_DIRECTIVES**

Controls whether `#line` directives appear in preprocessed output files.

---

**Note**

This qualifier has no effect on OpenVMS x86-64.

---

**/LIST****/LIST[=file-spec] (Batch default on Alpha and IA-64)****/NOLIST (Default on x86-64) (Interactive default on Alpha and IA-64)**

Controls whether a listing file is produced. The default output file extension is `.LIS`

**/MACHINE\_CODE****/NOMACHINE\_CODE (Default)**

Controls whether the listing produced by the compiler includes the machine-language code generated during the compilation. If you use this qualifier you also need to use the `/LIST` qualifier. On Alpha systems, machine-language code is not added to the listing file when object-file generation is disabled (using the `/NOOBJECT` qualifier).

---

**Note**

This qualifier has no effect on OpenVMS x86-64.

---

**/MAIN=POSIX\_EXIT****/MAIN=POSIX\_EXIT****/NOMAIN (Default)**

Directs the compiler to call `__posix_exit` instead of `exit` when returning from `main`.

---

**Note**

This qualifier has no effect on OpenVMS x86-64.

---

**/MEMBER\_ALIGNMENT****/MEMBER\_ALIGNMENT (Default)****/NOMEMBER\_ALIGNMENT**

Directs the compiler to naturally align data structure members. This means that data structure members are aligned on the next boundary appropriate to the type of the member, rather than on the next byte. For instance, a long variable member is aligned on the next longword boundary; a short variable member is aligned on the next word boundary.

Any use of the `#pragma member_alignment` or `#pragma nomember_alignment` directives within the source code overrides the setting established by this qualifier. Specifying



`/NOMEMBER_ALIGNMENT` causes data structure members to be byte-aligned (with the exception of bit-field members).

**`/MMS_DEPENDENCIES`****`/MMS_DEPENDENCIES[=(option[,option])]`****`/NOMMS_DEPENDENCIES (Default)`**

Instructs the compiler to produce a dependency file. The format of the dependency file is as follows:

```
object_file_name<space>:<tab><source file name>
object_file_name<space>:<tab><full path to first include file>
object_file_name<space>:<tab><full path to second include file>
```

You can specify none, one, or both of the following qualifier options:

<code>FILE[=filespec]</code>	Specifies where to save the dependency file. The default file extension for a dependency file is <code>.mms</code> . Other than using a different default extension, this qualifier uses the same procedure that <code>/OBJECT</code> and <code>/LIST</code> use for determining the name of the output file.
<code>SYSTEM_INCLUDE_FILES</code>	Specifies whether to include dependency information about system include files (that is, those included with <code>#include &lt;filename&gt;</code> ). The default is to include dependency information about system include files.

**`/MODEL (Alpha only)`****`/MODEL={ANSI | ARM}`****`/MODEL=ARM (Default)`**

On Alpha systems, determines the layout of C++ classes, name mangling, and exception handling.

On IA-64 systems, the default (and only) object model & demangling scheme used is the IA-64 Application Binary Interface (ABI). The compiler accepts the `/MODEL` qualifier, but it has no effect.

On Alpha systems, `/MODEL=ARM` is the default and generates objects that are link compatible with all releases prior to VSI C++ version 6.3, and with all objects compiled with the `/MODEL=ARM` qualifier in releases of VSI C++ Version 6.3 or later. Specifying this option defines the macro `__MODEL_ARM`.

The `/MODEL=ANSI` qualifier supports the complete ISO/ANSI C++ specification, including distinct name mangling for templates. The ANSI model also reduces the size of C++ non-POD class objects. Note that this option generates objects that are not compatible with all prior and future releases of VSI C++, or with objects compiled using the `/MODEL=ARM` qualifier.

If you specify the `/MODEL=ANSI` qualifier, you must recompile and relink (using `CXXLINK/MODEL=ANSI`) your entire application, including libraries. Specifying this option defines the macro `__MODEL_ANSI`.

---

**Note**

This qualifier has no effect on OpenVMS x86-64.

---

**/NAMES****/NAMES=(option1,option2)****/NAMES=(UPPERCASE,TRUNCATED) (Default on Alpha and IA-64)****/NAMES=AS\_IS (Default on x86-64)**

Option1 converts all definitions and references of external symbols and psects to the case specified.

Option1 values are:

Option	Usage
UPPERCASE	Converts to uppercase.
AS_IS	Leaves the case as specified in the source.

Option2 controls whether or not external names greater than 31 characters get truncated or shortened. Option2 values are:

Option	Usage
/NAMES=TRUNCATED	Truncates long external names to the first 31 characters.
/NAMES=SHORTENED	Shortens long external names.  A shortened name consists of the first 23 characters of the name followed by a 7-character Cyclic Redundancy Check (CRC) computed by looking at the full name, and then a "\$".

On Alpha and IA-64 systems, the default is /NAMES=(UPPERCASE,TRUNCATED). On x86-64 systems, the default is /NAMES=AS\_IS, and keeps the "full-length" of the name.

**Note**

On IA-64 systems, the C++ compiler has some additional encoding rules that are applied to symbol names after the ABI name mangling is determined. All symbols with C++ linkage have CRC encodings added to the name, are upcased and shorten to 31 characters if necessary. Since the CRC is computed before the name is upcased, the symbol name is case-sensitive even though the final name is in uppercase. /NAMES=AS\_IS and /NAMES=UPPER are not applicable to these symbols. All symbols without C++ linkage will have CRC encodings added if they are longer than 31 characters and /NAMES=SHORTENED is specified. Global variables with C++ linkage are treated as if they have non-C++ linkage for compatibility with C and older compilers.

On x86-64 systems, all symbols without C++ linkage will have CRC encodings added if they are longer than 31 characters and /NAMES=SHORTENED is specified.

**/NESTED\_INCLUDE\_DIRECTORY****/NESTED\_INCLUDE\_DIRECTORY[=option]****/NESTED\_INCLUDE\_DIRECTORY=INCLUDE\_FILE (Default)**

Controls the first step in the search algorithm the compiler uses when looking for files included using the quoted form of the #include preprocessing directive: #include "file-spec" The /NESTED\_INCLUDE\_DIRECTORY qualifier has the following options:

Option	Usage
PRIMARY_FILE	Directs the compiler to search the default file type for headers using the context of the primary source file. This means that only the file type

Option	Usage
	(".H" or ".") is used for the default file-spec but, in addition, the chain of "related file-specs" used to maintain the sticky defaults for processing the next top-level source file is applied when searching for the include file.  On x86-64 systems, this option is accepted but has no effect.
INCLUDE_FILE	Directs the compiler to search the directory containing the file in which the #include directive itself occurred. The meaning of "directory containing" is: the RMS "resultant string" obtained when the file in which the #include occurred was opened, except that the filename and subsequent components are replaced by the default file type for headers (".H", or just "." if /ASSUME=NOHEADER_TYPE_DEFAULT is in effect). The "resultant string" will not have translated any concealed device logical.
NONE	Directs the compiler to skip the first step of processing #include "file.h" directives. The compiler starts its search for the include file in the /INCLUDE_DIRECTORY directories.

For more information on the search order for included files, see the /INCLUDE\_DIRECTORY qualifier.

**/OBJECT**  
**/OBJECT[=file-spec]**  
**/OBJECT=.OBJ (Default)**  
**/NOOBJECT**

Controls whether the compiler produces an output object module. The default output file extension is .OBJ.

Note that the /OBJECT qualifier has no impact on the output file of the /MMS\_DEPENDENCIES qualifier.

**/OPTIMIZE**  
**/OPTIMIZE[=option]**  
**/OPTIMIZE=(LEVEL=4,INLINE=AUTOMATIC,INTRINSICS,UNROLL=0,**  
**NOOVERRIDE\_LIMITS,TUNE=GENERIC) (Default)**  
**/NOOPTIMIZE**

Controls the level of code optimization that the compiler performs. The options are as follows:

Option	Usage
LEVEL=n	Selects the level of code optimization. Specify an integer from 0 (no optimization) to 5 (full optimization).
[NO]INLINE	Provides inline expansion of functions that yield optimized code when they are expanded. You can specify one of the following keywords to control inlining:
	NONE No inlining is done, even if requested by the language syntax.
	MANUAL Inlines only those function calls for which the program explicitly requests inlining. Has the same effect of INLINE as x86-64.

Option	Usage
	<p><b>AUTOMATIC</b></p> <p>Inlines all of the function calls in the MANUAL category, plus additional calls that the compiler determines are appropriate on this platform. On Alpha systems, the heuristics for AUTOMATIC are similar to those for SIZE; on IA-64 systems, they are more like those for SPEED. AUTOMATIC is the default. Has the same effect of INLINE as x86-64.</p>
	<p><b>SIZE</b></p> <p>Inlines all of the function calls in the MANUAL category plus any additional calls that the compiler determines would improve run-time performance without significantly increasing the size of the program. Has the same effect of INLINE as x86-64.</p>
	<p><b>SPEED</b></p> <p>Performs more aggressive inlining for run-time performance, even when it might significantly increase the size of the program. Has the same effect as INLINE on x86-64.</p>
	<p><b>ALL</b></p> <p>Inlines every call that can be inlined while still generating correct code. Recursive routines, however, will not cause an infinite loop at compile time. On IA-64 systems, ALL is treated as if SIZE had been specified.</p> <p>Note that /OPT=INLINE=ALL is not recommended for general use, because it performs very aggressive inlining and can cause the compiler to exhaust virtual memory or take an unacceptably long time to compile.</p> <p>Has the same effect as INLINE on x86-64.</p>
<p><b>[NO]OVERRIDE_LIMITS</b> (IA-64 only)</p>	<p>Controls whether or not the compiler uses certain built-in limits on the size and complexity of a function to "throttle back" the amount of optimization performed in order to reduce the likelihood that the compiler will use excessive memory resources or CPU time attempting to optimize the code.</p> <p>The default is NOOVERRIDE_LIMITS, which means that when compiling a function that has an unusually large number of basic blocks, live variables, or other properties that tend to cause the optimizer to use extra resources, the informational message OPTLIMEXC might be issued to notify you that optimization has been reduced to avoid excessive resource use.</p> <p>You can choose to ignore this message or disable it (the message is not issued on compilations with optimization disabled).</p> <p>Or you can specify /OPTIMIZE=OVERRIDE_LIMITS, which instructs the compiler to not check the limits and to attempt full</p>

Option	Usage										
	<p>optimization no matter how large or complex the function, knowing that the compilation might exhaust memory or seem to be in a loop.</p> <p>If using <code>/OPTIMIZE=OVERRIDE_LIMITS</code> does result in excessive resource use, you are sure that the compiler process has plenty of memory quota available, you are convinced that the compilation does not contain any unusually large or complex functions, and you can provide complete source code, then you might want to contact your support channel to see if there is a problem in the compiler causing it to use more resources than it should for the particular compilation at hand.</p> <p>Has no effect on x86-64.</p>										
TUNE	<p>Specifies the preferred processor for execution. This option makes some decisions preferentially for the specified processor (for example, for code scheduling). Note that code valid only for the specified processor can be generated. However, parallel code can be generated for processors down to the specified architecture level if necessary; that is, tuning specifies the preferred target, while architecture level specifies a lower boundary on available processor features.</p> <p>For example, <code>/ARCHITECTURE=EV56/OPTIMIZE=TUNE=EV6</code> specifies that the code does not need to run on a processor older than an EV56, and that the code will probably run on an EV6. The generated code will run on all EV56 and later systems without any emulation. The code might have run-time selected conditional regions specifically for EV6. Also, note that because emulation is provided, the code should run, but potentially at very significantly reduced speed, on pre-EV56 processors.</p> <p>Has no effect on x86-64.</p> <p>The options for TUNE are the same as the options for <code>/ARCH</code>. You can specify one of the following keywords:</p> <table> <tr> <td>GENERIC</td><td>Selects instruction tuning that is appropriate for all implementations of the operating system architecture. This option is the default.</td></tr> <tr> <td>HOST</td><td>Selects instruction tuning that is appropriate for the machine on which the code is being compiled.</td></tr> <tr> <td>ITANIUM2 (IA-64 only)</td><td>Selects instruction tuning for the Intel Itanium 2 processor.</td></tr> <tr> <td>EV5 (Alpha only)</td><td>Selects instruction tuning for the 21164 implementation of the operating system architecture.</td></tr> <tr> <td>EV56 (Alpha only)</td><td>Selects instruction tuning for the 21164 implementation of the operating system architecture.</td></tr> </table>	GENERIC	Selects instruction tuning that is appropriate for all implementations of the operating system architecture. This option is the default.	HOST	Selects instruction tuning that is appropriate for the machine on which the code is being compiled.	ITANIUM2 (IA-64 only)	Selects instruction tuning for the Intel Itanium 2 processor.	EV5 (Alpha only)	Selects instruction tuning for the 21164 implementation of the operating system architecture.	EV56 (Alpha only)	Selects instruction tuning for the 21164 implementation of the operating system architecture.
GENERIC	Selects instruction tuning that is appropriate for all implementations of the operating system architecture. This option is the default.										
HOST	Selects instruction tuning that is appropriate for the machine on which the code is being compiled.										
ITANIUM2 (IA-64 only)	Selects instruction tuning for the Intel Itanium 2 processor.										
EV5 (Alpha only)	Selects instruction tuning for the 21164 implementation of the operating system architecture.										
EV56 (Alpha only)	Selects instruction tuning for the 21164 implementation of the operating system architecture.										

Option	Usage
	<p><b>PCA56 (<i>Alpha only</i>)</b></p> <p>Selects instruction tuning for 21164 chip implementations that use the byte- and word-manipulation instruction extensions of the Alpha architecture.</p> <p>Running programs compiled with the EV56 keyword might incur emulation overhead on EV4 and EV5 processors, but will still run correctly on OpenVMS Version 7.1 (or later) systems.</p>
	<p><b>PCA56 (<i>Alpha only</i>)</b></p> <p>Selects instruction tuning for the 21164PC chip implementation that uses the byte- and word-manipulation instruction extensions and multimedia instruction extensions of the Alpha architecture.</p> <p>Programs compiled with the PCA56 keyword might incur emulation overhead on EV4, EV5, and EV56 processors, but will still run correctly on OpenVMS Version 7.1 (or later) systems.</p>
	<p><b>EV6 (<i>Alpha only</i>)</b></p> <p>Selects instruction tuning for the first-generation 21264 implementation of the Alpha architecture.</p>
	<p><b>EV67 (<i>Alpha only</i>)</b></p> <p>Selects instruction tuning for the second-generation 21264 implementation of the Alpha architecture.</p>
[NO]INTRINSICS	<p>Controls whether certain functions are handled as intrinsic functions without explicitly enabling each of them as an intrinsic through the <code>#pragma intrinsic</code> preprocessor directive.</p> <p>Functions that can be handled as intrinsics are:</p> <p><b>Main Group - ANSI:</b></p> <pre>abs  atanl  atan2l  ceill  cosl  floorf  memcpy  sinf atan  atan  ceil  cos  fabs  floorl  memmove  sinl  sin atanf  atan2f  ceilf  cosf  floor  labs  memset  strcpy  strlen</pre> <p><b>Main Group - Non-ANSI:</b></p> <pre>alloca  atand2  bzero  sind atand  bcopy  cosd</pre> <p><b>Printf functions:</b></p> <pre>fprintf  printf  sprintf</pre> <p><b>Printf non-ANSI:</b></p> <pre>snprintf</pre> <p><b>ANSI math functions that set errno, thereby requiring / ASSUME=NOMATH_ERRNO:</b></p> <pre>acos  asinf  coshl  log  log10f  powl  sqrt  tanf acosf  asinl  exp  logf  log10l  sinh  sqrtf  tanl</pre>

Option	Usage
	<p> <code>acosl cosh expf logl pow sinhf sqrtl tanh tanhl</code>  <code>asin coshf expl log10 powf sinhl tan tanhf</code> </p> <p><b>Non-ANSI math functions that set <code>errno</code>, thereby requiring <code>/ASSUME=NOMATH_ERRNO</code>:</b></p> <p><code>log2 tand</code></p> <p>The <code>/OPTIMIZE=INTRINSICS</code> qualifier works with <code>/OPTIMIZE=LEVEL=n</code> and some other qualifiers to determine how intrinsics are handled:</p> <ul style="list-style-type: none"> <li>• If the optimization level specified is less than 4, the intrinsic-function prototypes and call formats are checked, but normal run-time calls are still made.</li> <li>• If the optimization level is 4 or higher, intrinsic code is generated.</li> <li>• Intrinsic code is not generated for math functions that set the <code>errno</code> variable unless <code>/ASSUME=NOMATH_ERRNO</code> is specified. Such math functions, however, do have their prototypes and call formats checked.</li> </ul> <p>The default is <code>/OPTIMIZE=INTRINSICS</code>, which turns on this handling.</p> <p>To turn it off, use <code>/NOOPTIMIZE</code> or <code>/OPTIMIZE=NOINTRINSICS</code>.</p> <p>Has no effect on x86-64.</p>
<code>UNROLL=n</code>	<p>Controls loop unrolling done by the optimizer. Specify a positive integer to indicate the number of times to unroll loop bodies. If you specify 0 or do not supply a value, the optimizer determines its own unroll amount. The default is <code>UNROLL=0</code>. Specifying <code>UNROLL=1</code> effectively disables loop unrolling.</p> <p>On IA-64 systems, you do not have the ability to control the number of times a loop is unrolled. You can either disable loop unrolling with <code>UNROLL=1</code>, or accept the <code>UNROLL=0</code> default, which lets the optimizer determine the unroll amount.</p> <p>Has no effect on x86-64.</p>

The default is `/OPTIMIZE`, which is equivalent to `/OPTIMIZE=LEVEL=4`.

**`/PENDING_INSTANTIATIONS`**  
**`/PENDING_INSTANTIATIONS[=n]`**  
**`/PENDING_INSTANTIATIONS=64 (Default)`**

Limit the depth of recursive instantiations so that infinite instantiation loops can be detected before some resource is exhausted. The `/PENDING_INSTANTIATIONS` qualifier requires a positive non-zero value as argument and issues an error when `n` instantiations are pending for the same class template. The default value for `n` is 64.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

### **/POINTER\_SIZE**

#### **/POINTER\_SIZE=option**

#### **/NOPOINTER\_SIZE (Default)**

Controls whether pointer-size features are enabled, and whether pointers are 32 bits or 64 bits long.

On Alpha and IA-64 systems, the default is `/NOPOINTER_SIZE`, which disables pointer-size features, such as the ability to use `#pragma pointer_size`, and directs the compiler to assume that all pointers are 32-bit pointers. This default represents no change over previous versions of VSI C++. On x86-64 systems, the default is also `/NOPOINTER_SIZE`, but this directs the compiler to assume that all pointers are 64-bit pointers.

You can specify one of the following options:

SHORT	The compiler assumes 32-bit pointers.
32	Same as SHORT.
LONG	The compiler assumes 64-bit pointers.
LONG[=ARGV]	The compiler assumes 64-bit pointers. If the ARGV option to LONG or 64 is present, the main argument <code>argv</code> will be an array of long pointers instead of an array of short pointers. ( <i>IA-64 and x86-64 only</i> )
64	Same as LONG.

Specifying `/POINTER_SIZE=32` directs the compiler to assume that all pointers are 32-bit pointers. But unlike the default of `/NOPOINTER_SIZE`, `/POINTER_SIZE=32` enables use of the `#pragma pointer_size long` and `#pragma pointer_size short` preprocessor directives to control pointer size throughout your program.

Specifying `/POINTER_SIZE=64` directs the compiler to assume that all pointers are 64-bit pointers, and also enables use of the `#pragma pointer_size` directives.

### **/PREFIX\_LIBRARY\_ENTRIES**

#### **/PREFIX\_LIBRARY\_ENTRIES=(option,...)**

#### **/NOPREFIX\_LIBRARY\_ENTRIES**

#### **/PREFIX\_LIBRARY\_ENTRIES=ALL\_ENTRIES (Default)**

Controls C Run-Time Library (RTL) name prefixing. For user programs that do not include the ANSI header files but call the ANSI library, the compiler automatically adds a `DECC$` prefix to all C RTL library calls just before the name for the external reference or global definition is put into the object file. The C RTL shareable image (`DECC$SHR.EXE`) resides in `IMAGELIB.OLB` with a `DECC$` prefix for its entry points. Every external name in `IMAGELIB.OLB` has a `DECC$` prefix, and, therefore, has an OpenVMS-conformant name space (a requirement for inclusion in `IMAGELIB`).

The options are as follows. Note that, on x86-64 systems, the following options have no effect:

Option	Usage
<code>EXCEPT=(name,...)</code>	The names specified are not prefixed.



Option	Usage
ALL_ENTRIES	All VSI C++ names are prefixed.  Note: ALL_ENTRIES prefixes all functions defined by the C99 standard, including those that may not be supported in the current run-time library. So calling functions introduced in C99 that are not yet implemented in the OpenVMS C RTL will produce unresolved references to symbols prefixed by DECC\$ when the program is linked. In addition, the compiler will issue a CC-W-NOTINCTRL message when it prefixes a name that is not in the current C RTL.
ANSI_C89_ENTRIES	Only ANSI/ISO C library names are prefixed.
RTL=name	References to the C RTL, indicated by NAME, are generated. NAME must be 1017 characters or fewer.

If you want no names prefixed, specify /NOPREFIX\_LIBRARY\_ENTRIES.

#### **/PREPROCESS\_ONLY**

**/PREPROCESS\_ONLY[=filename]**

**/NOPREPROCESS\_ONLY (Default)**

Causes the compiler to perform only the actions of the preprocessor phase and write the resulting processed text out to a file. The default output file extension is .IXX. Use of /PREPROCESS\_ONLY prevents the generation of an object file. On Alpha and IA-64, /PREPROCESS\_ONLY additionally prevents the generation of an XREF file.

#### **/PSECT\_MODEL**

**/PSECT\_MODEL=MULTILANGUAGE**

**/PSECT\_MODEL=NOMULTILANGUAGE (Default)**

Controls whether the compiler allocates the size of overlaid psects to ensure compatibility when the psect is shared by code created by other VSI compilers.

This qualifier solves a problem that can occur when a psect generated by a Fortran COMMON block is overlaid with a psect consisting of a C struct. Because Fortran COMMON blocks are not padded, if the C struct is padded, the inconsistent psect sizes can cause linker error messages.

Compiling with /PSECT\_MODEL=MULTILANGUAGE ensures that the compiler uses a consistent psect size allocation scheme. The corresponding Fortran qualifier is /ALIGN=COMMON=[NO]MULTILANGUAGE.

The default is /PSECT=NOMULTILANGUAGE, which should be sufficient for most applications.

---

### **Note**

This qualifier has no effect on OpenVMS x86-64.

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#### **/PURE\_CNAME**

**/PURE\_CNAME (Default) (/STANDARD=STRICT\_ANSI)**

**/NOPURE\_CNAME (Default) (All other modes)**

Affects insertion of the names into the global namespace by <cname> headers.

In `/PURE_CNAME` mode, the `<cname>` headers insert the names into the `std` namespace only, as defined by the C++ Standard. In this mode, the `__PURE_CNAME` and `__HIDE_FORBIDDEN_NAMES` macros are predefined by the compiler.

In `/NOPURE_CNAME` mode, the `<cname>` headers insert the name into the `std` namespace and also into the global namespace. In this mode, the `__PURE_CNAME` and `__HIDE_FORBIDDEN_NAMES` macros are not predefined by the compiler.

The default depends on the standard mode:

- In `/STANDARD=STRICT_ANSI` mode, the default is `/PURE_CNAME`.
- In all other standard modes, the default is `/NOPURE_CNAME`.

Inclusion of a `<name>` header instead of its `<cname>` counterpart (for example, `<stdio.h>` instead of `<cstdio>`) results in inserting names defined in the header into both the `std` namespace and the global namespace. Effectively, this is the same as the inclusion of a `<cname>` header in `/NOPURE_CNAME` mode.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

## **`/QUIET`**

## **`/QUIET`**

## **`/NOQUIET (Default)`**

Specifying `/QUIET` causes the compiler to report errors like the Version 5.n compiler (issue fewer messages). This is the default for ARM mode (`/STANDARD=ARM`). All other modes default to `/NOQUIET`.

Use `/WARNINGS=ENABLE` to enable specific messages normally disabled with `/QUIET`.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

## **`/REENTRANCY`**

## **`/REENTRANCY=option`**

## **`/REENTRANCY=TOLERANT (Default)`**

Controls the type of reentrancy that reentrant C RTL routines exhibit. (See also the `DECC$SET_REENTRANCY` RTL routine.)

This qualifier is for use only with a module containing the main routine.

The reentrancy level is set at run time according to the `/REENTRANCY` qualifier specified while compiling the module containing the main routine. This option affects the behavior of the C RTL, but has no effect on the C++ libraries.

You can specify one of the following options:

Option	Usage
AST	Uses the <code>__TESTBITSSI</code> built-in function to perform simple locking around critical sections of RTL code, and may additionally disable asynchronous system traps (ASTs) in locked region of codes. This type of locking should be used when AST code contains calls to VSI C RTL I/O routines.
MULTITHREAD	Designed to be used in conjunction with the DECthreads product. It performs DECthreads locking and never disables ASTs.
NONE	Gives optimal performance in the RTL, but does absolutely no locking around critical sections of RTL code. It should be used only in a single threaded environment when there is no chance that the thread of execution will be interrupted by an AST that would call the C RTL.
TOLERANT	Uses the <code>__TESTBITSSI</code> built-in function to perform simple locking around critical sections of RTL code, but ASTs are not disabled. This type of locking should be used when ASTs are used and must be delivered immediately. This is the default reentrancy type.

## Note

This qualifier has no effect on OpenVMS x86-64.

## /REPOSITORY

**/REPOSITORY=(PATHNAME [...])**

**/REPOSITORY=[.CXX\_REPOSITORY] (Default)**

Specifies a repository that C++ uses to store requested template instantiations. The default is `/REPOSITORY=[.CXX_REPOSITORY]`. If multiple repositories are specified, only the first is considered writable and the default repository is ignored unless specified.

## Note

This qualifier has no effect on OpenVMS x86-64.

## /ROUNDING\_MODE

**/ROUNDING\_MODE=option**

**/ROUNDING\_MODE=NEAREST (Default)**

Lets you select an IEEE rounding mode if `/FLOAT=IEEE_FLOAT` is specified. The options are as follows:

Option	Usage
CHOPPED	Rounds toward 0.

Option	Usage
DYNAMIC	Sets the rounding mode for IEEE floating-point instructions dynamically, as determined from the contents of the floating-point control register.
MINUS_INFINITY	Rounds toward minus infinity.
NEAREST	Sets the normal rounding mode (unbiased round to nearest). This is the default.

If you specify either `/FLOAT=G_FLOAT` or `/FLOAT=D_FLOAT`, then rounding defaults to `/ROUNDING_MODE=NEAREST`, with no other choice of rounding mode.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

### **/RTTI**

#### **/RTTI (Default)**

#### **/NORTTI** (*Alpha and x86-64 only*)

Enables or disables support for RTTI (runtime type identification) features: `dynamic_cast` and `typeid`. Disabling runtime type identification can also save space in your object file because static information to describe polymorphic C++ types is not generated. The default is to enable runtime type information features and generate static information in the object file. The `/RTTI` qualifier defines the macro `__RTTI`.

Note that specifying `/NORTTI` does not disable exception handling.

### **/SHARE\_GLOBALS**

#### **/SHARE\_GLOBALS**

#### **/NOSHARE\_GLOBALS** (Default)

Controls whether the initial `extern_model` is shared or not shared (for those `extern_models` where it is allowed). The initial `extern_model` of the compiler is a fictitious pragma constructed from the settings of the `/EXTERN_MODEL` and `/SHARE_GLOBALS`.

The default value is `/NOSHARE_GLOBALS`, which has the following effects:

- When linking old object files or object libraries with newly produced object files, you might get "conflicting attributes for psect" messages, which can be safely ignored as long as you are not building shareable libraries.
- The `/noshare_globals` default makes building shareable libraries easier.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

**/SHOW****/SHOW=(option[,...])****/SHOW=(HEADER,SOURCE) (Default)**

Used with the /LIST qualifier to set or cancel specific listing options. You can select the following options:

Option	Usage
ALL	Print all listing information.
[NO]HEADER	Print/do not print header lines at the top of each page (Default is HEADER).
[NO]INCLUDE	Print/do not print contents of <code>#include</code> files (Default is NOINCLUDE).
NONE	Print no listing information.
[NO]SOURCE	Print/do not print source file statements (Default is SOURCE).
[NO]EXPANSION ( <i>x86-64 only</i> )	Expand the <code>#if</code> and <code>#elif</code> preprocessor directives.
[NO]STATISTICS	Print/do not print compiler performance statistics (Default is NOSTATISTICS). On IA-64 and x86-64 systems, the /SHOW=STATISTICS option is ignored.

**/STANDARD****/STANDARD=(option)****/STANDARD=RELAXED (Default)**

The compiler implements the International ANSI C++ Standard. The /STANDARD qualifier directs the compiler to interpret source code according to certain nonstandard syntax conventions followed by other implementations of the C++ language.

On Alpha and IA-64 systems, the options are:

Option	Usage
RELAXED	Allow language constructs required by the International ANSI C++ Standard. This mode also supports some non-ANSI extensions and issues messages for some nonstandard usage that does not strictly comply with the standard. This is the default compiler mode. This option also defines the macro <code>__STD_ANSI</code> . Please note that ANSI is accepted as a synonym for RELAXED to be compatible with previous C++ versions.
ARM	Minimize source changes when compiling programs developed using Version 5.n. This option also defines the macro <code>__STD_ARM</code> . The /STANDARD=ARM qualifier uses the pre-ansi AT&T version of the iostream library and defines the macro <code>__NO_USE_STD_Iostream</code> .
CFRONT	Support for /STANDARD=CFRONT is retired.
GNU	Use this option if you want to compile programs developed using the GNU C++ compiler. This option also defines the <code>__STD_GNU</code> macro. The /STANDARD=GNU qualifier uses the pre-ansi AT&T version of the iostream library and defines the macro <code>__NO_USE_STD_Iostream</code> . The following changes in behavior are provided for compatibility with the GNU C++ compiler:

Option	Usage
	<ul style="list-style-type: none"> <li>These options are enabled by default:  <code>/ALTERNATIVE_TOKENS</code>  <code>/TEMPLATE_DEFINE=LOCAL</code>  <code>/NOIMPLICIT_INCLUDE</code> </li> <li>Access control is not enforced for types defined inside a class.</li> <li>Unrecognized character escape sequences in string literals produce an informational instead of a warning message.</li> <li>The <code>__INLINE</code> keyword is enabled and is equivalent to <code>inline</code>.</li> <li>The severity of the error "incompatible parameter" (tag <code>incompatibleprm</code>) is reduced to warning.</li> <li>When overloading, enum types are treated as integral types.</li> </ul> <p>The following known incompatibility is not addressed in the <code>/STANDARD=GNU</code> mode:</p> <ul style="list-style-type: none"> <li>The compiler strictly enforces the requirement to define functions before they are used. This requirement also applies to built-in functions such as <code>strlen</code>.</li> </ul>
MS	Allow language constructs supported by the Visual C++ compiler. This option also defines the macro <code>__STD_MS</code> . The <code>/STANDARD=MS</code> qualifier uses the pre-ansi AT&T version of the <code>iostream</code> library and defines the macro <code>__NO_USE_STD_Iostream</code> .
STRICT_ANSI	Enforce the ANSI standard strictly but permit some ANSI violations that should be errors to be warnings. This option also defines the macro <code>__STD_STRICT_ANSI</code> . To force ANSI violations to be issued as errors instead of warnings, use <code>/WARNINGS=ANSI_ERRORS</code> in addition to <code>/STANDARD=STRICT_ANSI</code> . This combination defines the macro <code>__STD_STRICT_ANSI_ERRORS</code> . The <code>/STANDARD=STRICT_ANSI</code> qualifier uses the ANSI/ISO standard version of the <code>iostream</code> library and defines the macro <code>__USE_STD_Iostream</code> .
LATEST	Latest C++ standard dialect ( <i>Alpha, IA-64</i> ). <code>/STANDARD=LATEST</code> is currently equivalent to <code>/STANDARD=STRICT_ANSI</code> , but is subject to change when newer versions of the C++ standard are released.

On x86-64 systems, the options are as follows. Note that options from other OpenVMS targets are accepted, but are ignored:

Option	Usage
GNU98	Implement C++98 standard with GNU extensions.
CXX98	Implement C++98 standard.
GNU03	Implement C++03 standard with GNU extensions.
CXX03	Implement C++03 standard.
GNU11	Implement C++11 standard with GNU extensions.
CXX11	Implement C++11 standard.

Option	Usage
GNU14	Implement C++14 standard with GNU extensions.
CXX14	Implement C++14 standard.
RELAXED	Implement C++98 standard with GNU extensions.
STRICT_ANSI	Implement C++98 standard.
LATEST	/STANDARD=LATEST is currently equivalent to /STANDARD=STRICT_ANSI, but is subject to change when newer versions of the C++ standard are released.

For more information on the effect of the /STANDARD qualifier on VSI C++ compile-time error checking, see *Section D.1, "Compatibility with Other C++ Compilers"*.

**/TEMPLATE\_DEFINE=(option,...)**

**/NOTEMPLATE\_DEFINE**

Controls compiler behavior pertaining to the instantiation of C++ templates. See *Chapter 6, "Using Templates"* for details on how to instantiate templates using this qualifier.

Note that you must specify a value for /TEMPLATE\_DEFINE.

Select only one of the following optional values to determine the template instantiation model:

Option	Usage
ALL	Instantiate all template entities declared or referenced in the compilation unit, including typedefs. For each fully instantiated template class, all its member functions and static data members are instantiated even if they were not used. Nonmember template functions are instantiated even if the only reference was a declaration. Instantiations are created with external linkage. Overrides /REPOSITORY at compile time. Instantiations are placed in the user's object file.
ALL_REPOSITORY	Instantiate all templates declared or used in the source program and put the object code generated as separate object files in the repository. Instantiations caused by manual instantiation directives are also put in the repository. This is similar to /TEMPLATE_DEFINE=ALL except that explicit instantiations are also put in the repository, rather than an external symbol being put in the main object file. This qualifier is useful for creating a pre-instantiation library.
AUTOMATIC	Directs the compiler to use the automatic instantiation model of C++ templates. /TEMPLATE_DEFINE=AUTOMATIC is the default.
NOAUTOMATIC	Directs the compiler to not implicitly instantiate templates.
IMPLICIT_LOCAL	Same as /TEMPLATE_DEFINE=LOCAL, except manually instantiated templates are placed in the repository with external linkage. This is useful for build systems that need to have explicit control of the template instantiation mechanism. This mode can suffer the same limitations as

Option	Usage
	/TEMPLATE_DEFINE=LOCAL. This mode is the default when /STANDARD=GNU is specified.
LOCAL	<p>Similar to /TEMPLATE_DEFINE=USED except that the functions are given internal linkage. This qualifier provides a simple mechanism for getting started with templates. The compiler instantiates as local functions the functions used in each compilation unit, and the program links and runs correctly (barring problems resulting from multiple copies of local static variables). However, because many copies of the instantiated functions can be generated, this qualifier might not be suitable for production use.</p> <p>The /TEMPLATE_DEFINE=LOCAL qualifier cannot be used in conjunction with automatic template instantiation. If automatic instantiation is enabled by default, it is disabled by the /TEMPLATE_DEFINE=LOCAL qualifier. Explicit use of /TEMPLATE_DEFINE=LOCAL and /TEMPLATE_DEFINE=AUTO is an error.</p>
USED	Instantiate those template entities that were used in the compilation. This includes all static data members for which there are template definitions. Overrides /TEMPLATE_DEFINE=AUTO at compile time.
USED_REPOSITORY	Like ALL_REPOSITORY, but instantiates only templates used by the compilation. The explicit instantiations are also put into the repository as separate object files.

The following /TEMPLATE\_DEFINE optional values are independent of the model used and each other:

Option	Usage
DEFINITION_FILE_TYPE="file-type-list"	Specifies a string that contains a list of file types that are valid for template definition files. Items in the list must be separated by commas and preceded by a period. A type is not allowed to exceed the OpenVMS limit of 31 characters. This qualifier is applicable only when automatic instantiation has been specified. The default is /TEMPLATE_DEFINE=DEF= ".CXX,.C,.CC,.CPP".
PRAGMA	Determines whether the compiler ignores #pragma define_template directives encountered during the compilation. This qualifier lets you quickly switch to automatic instantiation without having to remove all the pragma directives from your program's code base. The default is /TEMPLATE_DEFINE=PRAGMA, which enables #pragma define_template.
VERBOSE	Turns on verbose or verify mode to display each phase of instantiation as it occurs. During the compilation phase, informational level diagnostics are generated to indicate which templates are automatically being instantiated. This qualifier is useful as a debugging aid.



Option	Usage
<b>TIMESTAMP</b> ( <i>Alpha only</i> )	only applicable if a repository is being used. Causes the compiler to create a timestamp file named <b>TIMESTAMP</b> . in the repository. Thereafter, instantiations are added or regenerated only if needed; that is, if they do not already exist, or if existing ones are older than the timestamp. Also see <b>/REPOSITORY</b> .

Also see **/PENDING\_INSTANTIATIONS**.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

### **/UNDEFINE**

**/UNDEFINE=(identifier[,...])**

**/NOUNDEFINE (Default)**

Performs the same function as the `#undef` preprocessor directive: it cancels a macro definition.

The **/UNDEFINE** qualifier is useful for undefining the predefined C++ preprocessor constants. For example, if you use a preprocessor constant to conditionally compile segments of code specific to C++ for OpenVMS systems, you can undefine constants to see how the portable sections of your program execute. For example:

```
/UNDEFINE="deccxx"
```

When both **/DEFINE** and **/UNDEFINE** are present on the **CXX** command line, **/DEFINE** is evaluated before **/UNDEFINE**.

### **/UNSIGNED\_CHAR**

**/UNSIGNED\_CHAR**

**/NOUNSIGNED\_CHAR (Default)**

The **/UNSIGNED\_CHAR** qualifier changes the default for all char types from signed to unsigned. The **/NOUNSIGNED\_CHAR** qualifier causes all plain char declarations to have the same representation and set of values as signed char declarations.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

### **/USING\_STD**

**/USING\_STD**

**/NOUSING\_STD (Default)**

Controls whether standard library header files are processed as though the compiled code were written as follows:

```
using namespace std;  
#include <header>
```

These options are provided for compatibility for users who do not want to qualify use of each standard library name with `std::` or put `using namespace std;` at the top of their sources.

`/USING_STD` turns implicit using namespace `std` on; this is the default when compiling `/STANDARD=ARM`, `/STANDARD=GNU`, `/STANDARD=MS`, or `/STANDARD=RELAXED`.

`/NOUSING_STD` turns implicit using namespace `std` off; this is the default when compiling `/STANDARD=STRICT_ANSI`.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

### **`/VERBOSE` (*x86-64 only*)**

Generates the command as input by the user, sends it to Clang, and then runs the compiler.

### **`/VERSION`**

### **`/VERSION`**

### **`/NOVERSION` (Default)**

Causes the compiler to identify (print out) its version and operating system. The listing file also contains the compiler version. You cannot specify this qualifier with any other qualifiers.

### **`/WARNINGS`**

### **`/WARNINGS[=(option[,...])]`**

### **`/WARNINGS` (Default)**

### **`/NOWARNINGS`**

Controls the issuance of compiler diagnostic messages and lets you modify the severity of messages.

The default qualifier, `/WARNINGS`, outputs all enabled warning and informational messages for the compiler mode you are using. The `/NOWARNINGS` qualifier suppresses warning and informational messages. On x86-64 systems, these qualifiers only affect warning messages.

Options apply only to warning and informational messages.

The *message-list* in the following table of options can be any one of the following:

- A single message identifier (within parentheses, or not). The message identifier is the name following the message severity letter on the first line of an issued message. For example, in the following message, the message identifier is `GLOBAEXT`:

```
%CC-W-GLOBAEXT, a storage class of globaldef, globalref, or  
    globalvalue  
is a language extension.
```

- **Alpha and IA-64:** A comma-separated list of message identifiers, enclosed in parentheses.

**x86-64:** A comma-separated list of message identifiers in double quotes, enclosed in parentheses.

- The keyword ALL.

On Alpha and IA-64 systems, the options are processed and take effect in the following order:

NOWARNINGS	Suppresses warnings.
NOINFORMATIONALS	Suppresses informational messages.
ENABLE= <i>message-list</i>	Enables issuance of the specified messages. Can be used to enable specific messages that normally would not be issued when using /QUIET or messages disabled with /WARNINGS=DISABLE.
DISABLE= <i>message-list</i>	Disables issuance of the specified messages. Can be used for any nonerror message specified by a message number or tag. Specify ALL to suppress all informationals and warnings.
INFORMATIONALS= <i>message-list</i>	Sets the severity of all specified messages to Informational. Fatal and Error messages cannot be made less severe. Can also be used to enable informationals that are disabled by default.
WARNINGS= <i>message-list</i>	Sets the severity of the specified messages to Warning. Fatal and Error messages cannot be made less severe.
[NO]ANSI_ERRORS	Issues error messages for all ANSI violations when in STRICT_ANSI mode. The default is  /WARNINGS=NOANSI_ERRORS  .
[NO]TAGS	Displays a descriptive tag at the end of each message. "D" indicates that the severity of the message can be controlled from the command line. The tag displayed can be used as the message identifier in the /WARNINGS qualifier options.
ERRORS= <i>message-list</i>	Sets the severity of the specified messages to Error.  Supplied Error and Fatal messages cannot be made less severe. (Exception: A message can be upgraded from Error to Fatal, then later downgraded to Error again, but it can never be downgraded from Error.)  Warnings and Informationals can be made any severity.
FATALS= <i>message-list</i>	Sets the severity of the specified messages to Fatal.

On x86-64 systems, the options are processed and take effect in the following order:

NOWARNINGS	Suppresses warnings.
NOINFORMATIONALS	Has no effect.
ENABLE= <i>message-list</i>	Enables issuance of the specified messages. Can be used to enable specific messages that normally would not be issued when messages disabled with  /WARNINGS=DISABLE  Specify "all" to enable all warnings.

DISABLE= <i>message-list</i>	Disables issuance of the specified messages. Specify "all" to suppress all warnings.
INFORMATIONALS= <i>message-list</i>	Has no effect.
WARNINGS= <i>message-list</i>	Sets the severity of the specified messages to Warning.
[NO]ANSI_ERRORS	Has no effect.
[NO]TAGS	Has no effect.
ERRORS= <i>message-list</i>	Sets the severity of the specified messages to Error.

---

## Note

The above message names are those from the Clang compiler and are not the same as those found on Alpha or IA-64.

---

Example:

```
$ CXX /WARNINGS=DISABLE=("undefined-bool-conversion", "non-pod-varargs")  
  foo.cxx
```

Also, see the `#pragma message` preprocessor directive.

**/XREF (*Alpha only*)**

**/XREF[=*file-spec*]**

**/NOXREF (Default)**

Controls whether the compiler generates a file of source code analysis information. The default file name is the file name of the primary source file; the default file type is .XREF. Use the SCA IMPORT command to convert an .XREF file into an analysis data file that is ready for loading into an SCA library.

---

## Note

This qualifier has no effect on OpenVMS x86-64.

---

# Appendix B. Built-In Functions

This appendix describes the built-in functions available when you compile on OpenVMS systems. These functions allow you to access hardware and machine instructions directly.

These functions allow you to directly access hardware and machine instructions to perform operations that are cumbersome, slow, or impossible in other C++ compilers.

These functions are very efficient because they are built into the VSI C++ compiler. This means that a call to one of these functions does not result in a reference to a function in the VSI C Run-Time Library or to a function in your program. Instead, the compiler generates the machine instructions necessary to carry out the function directly at the call site. Because most of these built-in functions closely correspond to single Alpha, IA-64, or x86-64 machine instructions, the result is small, fast code.

Be sure to include the `<builtins.h>` header file in your source program to access these built-in functions. Definitions for return types `int64` and `uint64` are contained in the header file `<ints.h>`.

Some of the built-in functions have optional arguments or allow a particular argument to have one of many different types. To describe all valid combinations of arguments, the following built-in function descriptions list several different prototypes for the function. As long as a call to a built-in function matches one of the prototypes listed, the call is valid. Furthermore, any valid call to a built-in function behaves as if the corresponding prototype were in scope of the call. The compiler, therefore, performs the argument checking and conversions specified by that prototype.

The majority of the built-in functions are named after the processor instruction that they generate. The built-in functions provide direct and unencumbered access to those processor instructions. Any inherent limitations to those instructions are limitations to the built-in functions as well. For instance, the `MOV3` instruction and the `_MOV3` built-in function can move at most 65,535 characters.

For more information on the Alpha built-in functions, see the corresponding machine instructions in the *Alpha Architecture Handbook* or *Alpha Architecture Reference Manual*.

For more information on the IA-64 built-in functions, see the corresponding machine instructions in the *Intel® Itanium® Architecture Software Developer's Manual*.

For more information on the x86-64 built-in functions, see the corresponding machine instructions in the *Intel® 64 and IA-32 Architectures Software Developer Manuals*.

## B.1. Built-In Functions for Alpha Systems (Alpha only)

The following sections describe the VSI C++ built-in functions available on OpenVMS Alpha systems.

### B.1.1. Translation Macros

VSI C++ for OpenVMS systems does not support the built-in functions available for OpenVMS VAX systems. However, the `<builtins.h>` header file contains macro definitions that translate some VAX C built-in functions to the equivalent VSI C++ for OpenVMS built-in functions. Consequently, the following VAX C built-in functions are effectively supported:

`_BBCCI(position, address)`

```
_BBSSI(position, address)

_INSQHI(new_entry, head)

_INSQTI(new_entry, head)

_INSQUE(new_entry, predecessor)

_REMQHI(head, removed_entry)

_REMQTI(head, removed_entry)

_REMQUE(entry, removed_entry)

_PROBER(mode, length, address)

_PROBEW(mode, length, address)
```

For more detail on any of these functions, see `<builtins.h>` or the description of the corresponding native Alpha function in this chapter. For example, for a description of `_INSQHI`, see *the section called “\_\_PAL\_INSQHIL”*.

## B.1.2. Intrinsic Functions

VSI C++ on Alpha systems supports in-line assembly code, commonly called ASMs on UNIX platforms.

Like built-in functions, ASMs are implemented with a function-call syntax. But unlike built-in functions, to use ASMs you must include the `<c_asm.h>` header file containing prototypes for the three types of ASMs, and the `#pragma intrinsic` preprocessor directive.

Syntax:

```
__int64 asm(const char *, ...); /* for integer operations,
                                like mulq */

float fasm(const char *, ...); /* for single precision float
                                instructions */

double dasm(const char *, ...); /* for double precision float
                                instructions */

#pragma intrinsic (asm)
#pragma intrinsic (fasm)
#pragma intrinsic (dasm)
```

The first argument to the `asm`, `fasm`, or `dasm` function contains the instruction(s) to be generated inline and the metalanguage that describes the interpretation of the arguments.

The remaining arguments (if any) are the source and destination arguments for the instruction being generated.

## B.1.3. Privileged Architecture Library Code Instructions

The following Privileged Architecture Library Code (PALcode) instructions are available as built-in functions:

__PAL_GENTRAP	__PAL_INSQHIL	__PAL_REMQHIL	__PAL_MTPR_ASTEN
__PAL_MFPR_ASTEN			
__PAL_HALT	__PAL_INSQTIL	__PAL_REMQTIL	__PAL_MTPR_ASTSR
__PAL_MFPR_ASTSR			
__PAL_PROBER	__PAL_INSQUEL	__PAL_REMQUEL	__PAL_MTPR_DATFX
__PAL_MFPR_ESP			
__PAL_PROBEW	__PAL_INSQHIQ	__PAL_REMQHIQ	__PAL_MTPR_ESP
__PAL_MFPR_FEN			
__PAL_CHME	__PAL_INSQTIQ	__PAL_REMQTIQ	__PAL_MTPR_FEN
__PAL_MFPR_IPL			
__PAL_CHMK	__PAL_INSQUEQ	__PAL_REMQUEQ	__PAL_MTPR_IPIR
__PAL_MFPR_MCES			
__PAL_CHMS	__PAL_INSQUEL_D	__PAL_REMQUEL_D	__PAL_MTPR_IPL
__PAL_MFPR_PCBB			
__PAL_CHMU	__PAL_INSQUEQ_D	__PAL_REMQUEQ_D	__PAL_MTPR_MCES
__PAL_MFPR_PRBR			
__PAL_LDQP	__PAL_INSQHILR	__PAL_REMQHILR	__PAL_MTPR_PRBR
__PAL_MFPR_PTBR			
__PAL_STOP	__PAL_INSQTILR	__PAL_REMQTILR	__PAL_MTPR_SCBB
__PAL_MFPR_SCBB			
__PAL_BPT	__PAL_INSQHIOQ	__PAL_REMQHIOQ	__PAL_MTPR_SIRR
__PAL_MFPR_SISR			
__PAL_BUGCHK	__PAL_INSQTIQ	__PAL_REMQTIQ	__PAL_MTPR_SSP
__PAL_MFPR_SSP			
__PAL_CFLUSH			__PAL_MTPR_TBIA
__PAL_MFPR_TBCHK			
__PAL_DRAIN			__PAL_MTPR_TBIAP
__PAL_MFPR_USP			
__PAL_RD_PS			__PAL_MTPR_TBIS
__PAL_MFPR_VPTB			
__PAL_SWPCTX			__PAL_MTPR_TBISD
__PAL_MFPR_WHAMI			
__PAL_SWASTEN			__PAL_MTPR_TBISI
__PAL_WR_PS_SW			__PAL_MTPR_USP
__PAL_IMB			__PAL_MTPR_VPTB

The following sections describe these PALcodes.

## **\_\_PAL\_BPT**

This function is provided for program debugging. It generates a Breakpoint trap.

This function has the following format:

```
void __PAL_BPT (void);
```

## **\_\_PAL\_BUGCHK**

This function is provided for error reporting. It generates a Bug-check trap.

This function has the following format:

## **\_\_PAL\_CFLUSH**

This function flushes at least the entire physical page specified by the page frame number *value* from any data caches associated with the current processor. After a CFLUSH is done, the first subsequent load on the same processor to an arbitrary address in the target page is fetched from physical memory.

This function has the following format:

```
void __PAL_CFLUSH (int value);
```

**value**

A page frame number.

## **\_\_PAL\_CHME**

This function allows a process to change its mode to Executive in a controlled manner. The change in mode also results in a change of stack pointers: the old pointer is saved and the new pointer is loaded. Registers R2 to R7, PS, and PC are pushed onto the selected stack. The saved PC addresses the instruction following the CHME instruction.

This function has the following format:

```
void __PAL_CHME (void);
```

## **\_\_PAL\_CHMK**

This function allows a process to change its mode to kernel in a controlled manner. The change in mode also results in a change of stack pointers: the old pointer is saved and the new pointer is loaded. Registers R2 to R7, PS, and PC are pushed onto the kernel stack. The saved PC addresses the instruction following the CHMK instruction.

This function has the following format:

```
void __PAL_CHMK (void);
```

## **\_\_PAL\_CHMS**

This function allows a process to change its mode to Supervisor in a controlled manner. The change in mode also results in a change of stack pointers: the old pointer is saved and the new pointer is loaded. Registers R2 to R7, PS, and PC are pushed onto the selected stack. The saved PC addresses the instruction following the CHMS instruction.

This function has the following format:

```
void __PAL_CHMS (void);
```

## **\_\_PAL\_CHMU**

This function allows a process to call a routine using the change mode mechanism. Registers R2 to R7, PS, and PC are pushed onto the current stack. The saved PC addresses the instruction following the CHMU instruction.

This function has the following format:

```
void __PAL_CHMU (void);
```

## **\_\_PAL\_DRAIN**

This function stalls instruction issuing until all prior instructions are guaranteed to complete without incurring aborts.



This function has the following format:

```
void __PAL_DRAIN (void);
```

## **\_\_PAL\_GENTRAP**

This function is used for reporting run-time software conditions. It generates a Software trap.

This function has the following format:

```
void __PAL_GENTRAP (unsigned __int64 encoded_software_trap);
```

**encoded\_software\_trap**

The particular software condition that has occurred.

## **\_\_PAL\_HALT**

This function halts the processor when executed by a process running in kernel mode. This is a privileged function.

This function has the following format:

```
void __PAL_HALT (void);
```

## **\_\_PAL\_IMB**

This function makes the instruction stream coherent with the data stream. It must be executed after software or I/O devices write into the instruction stream or modify the instruction stream virtual address mapping, and before the new value is fetched as an instruction. Note that executing an IMB on one processor in a multiprocessor environment does not affect instruction caches on other processors.

This function has the following format:

```
void __PAL_IMB (void);
```

## **\_\_PAL\_INSQHIL**

This function inserts an entry at the front of a longword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to header and queue entries. The pointers to *head* and *new\_entry* must not be equal.

This function has the following format:

```
int __PAL_INSQHIL (void *head, void *new_entry);  
/* At head, interlocked */
```

**head**

A pointer to the queue header. The header must be aligned on a quadword boundary.

**new\_entry**

A pointer to the new entry to be inserted. The entry must be aligned on a longword boundary.

There are three possible return values:

- -1 if the entry was not inserted because the secondary interlock failed
- 0 if the entry was inserted but it was not the only entry in the list
- 1 if the entry was inserted and it was the only entry in the list

## **\_\_PAL\_INSQHILR**

This function inserts an entry into the front of a longword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries. The pointers to *head* and *new\_entry* must not be equal. All parts of the queue must be memory resident.

This function has the following format:

```
int __PAL_INSQHILR (void *head, void *new_entry);  
/* At head, interlocked resident */
```

### **head**

A pointer to the queue header. The header must be aligned on a quadword boundary.

### **new\_entry**

A pointer to the new entry to be inserted. The entry must be aligned on a quadword boundary.

There are three possible return values:

- -1 if the entry was not inserted because the secondary interlock failed
- 0 if the entry was inserted but it was not the only entry in the list
- 1 if the entry was inserted and it was the only entry in the list

## **\_\_PAL\_INSQHIQ**

This function inserts an entry at the front of a quadword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to header and queue entries. The pointers to *head* and *new\_entry* must not be equal.

This function has the following format:

```
int __PAL_INSQHIQ (void *head, void *new_entry);  
/* At head, interlocked */
```

### **head**

A pointer to the queue header. The header must be aligned on an octaword boundary.

### **new\_entry**

A pointer to the new entry to be inserted. The entry must be aligned on an octaword boundary.

There are three possible return values:

- -1 if the entry was not inserted because the secondary interlock failed

- 0 if the entry was inserted but it was not the only entry in the list
- 1 if the entry was inserted and it was the only entry in the list

## **\_\_PAL\_INSQHIQR**

This function inserts an entry into the front of a quadword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries. The pointers to *head* and *new\_entry* must not be equal. All parts of the queue must be memory resident.

This function has the following format:

```
int __PAL_INSQHIQR (void *head, void *new_entry);  
/* At head, interlocked resident */
```

### **head**

A pointer to the queue header. The header must be aligned on an octaword boundary.

### **new\_entry**

A pointer to the new entry to be inserted. The entry must be aligned on an octaword boundary.

There are three possible return values:

- -1 if the entry was not inserted because the secondary interlock failed
- 0 if the entry was inserted but it was not the only entry in the list
- 1 if the entry was inserted and it was the only entry in the list

## **\_\_PAL\_INSQTIL**

This function inserts an entry at the end of a longword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to header and queue entries. The pointers to *head* and *new\_entry* must not be equal.

This function has the following format:

```
int __PAL_INSQTIL (void *head, void *new_entry);  
/* At tail, interlocked */
```

### **head**

A pointer to the queue header. The header must be aligned on a quadword boundary.

### **new\_entry**

A pointer to the new entry to be inserted. The entry must be aligned on a quadword boundary.

There are three possible return values:

- -1 if the entry was not inserted because the secondary interlock failed
- 0 if the entry was inserted but it was not the only entry in the list

- 1 if the entry was inserted and it was the only entry in the list

## **\_\_PAL\_INSQTILR**

This function inserts an entry at the end of a longword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries. The pointers to *head* and *new\_entry* must not be equal. All parts of the queue must be memory resident.

This function has the following format:

```
int __PAL_INSQTILR (void *head, void *new_entry);  
/* At tail, interlocked resident */
```

### **head**

A pointer to the queue header. The header must be aligned on a quadword boundary.

### **new\_entry**

A pointer to the new entry to be inserted. The entry must be aligned on a quadword boundary.

There are three possible return values:

- -1 if the entry was not inserted because the secondary interlock failed
- 0 if the entry was inserted but it was not the only entry in the list
- 1 if the entry was inserted and it was the only entry in the list

## **\_\_PAL\_INSQTIQ**

This function inserts an entry at the end of a quadword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to header and queue entries. The pointers to *head* and *new\_entry* must not be equal.

This function has the following format:

```
int __PAL_INSQTIQ (void *head, void *new_entry);  
/* At tail, interlocked */
```

### **head**

A pointer to the queue header. The header must be aligned on an octaword boundary.

### **new\_entry**

A pointer to the new entry to be inserted. The entry must be aligned on an octaword boundary.

There are three possible return values:

- -1 if the entry was not inserted because the secondary interlock failed
- 0 if the entry was inserted but it was not the only entry in the list
- 1 if the entry was inserted and it was the only entry in the list

## **\_\_PAL\_INSQTIQR**

This function inserts an entry at the end of a quadword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries. The pointers to *head* and *new\_entry* must not be equal. All parts of the queue must be memory resident.

This function has the following format:

```
int __PAL_INSQTIQR (void *head, void *new_entry);  
/* At tail, interlocked resident */
```

### **head**

A pointer to the queue header. The header must be aligned on an octaword boundary.

### **new\_entry**

A pointer to the new entry to be inserted. The entry must be aligned on an octaword boundary.

There are three possible return values:

- -1 if the entry was not inserted because the secondary interlock failed
- 0 if the entry was inserted but it was not the only entry in the list
- 1 if the entry was inserted and it was the only entry in the list

## **\_\_PAL\_INSQUEL**

This function inserts a new entry after an existing entry into a longword queue. This function must have write access to header and queue entries.

This function has the following format:

```
int __PAL_INSQUEL (void *predecessor, void *new_entry);
```

### **predecessor**

A pointer to an existing entry in the queue.

### **new\_entry**

A pointer to the new entry to be inserted.

There are two possible return values:

- 0 if the entry was not the only entry in the queue
- 1 if the entry was the only entry in the queue

## **\_\_PAL\_INSQUEL\_D**

This function inserts a new entry after an existing entry into a longword queue deferred. This function must have write access to header and queue entries.

This function has the following format:

```
int __PAL_INSQUEL_D (void **predecessor, void *new_entry);  
/* Deferred */
```

**predecessor**

A pointer to a pointer to the predecessor entry.

**new\_entry**

A pointer to the new entry to be inserted.

There are two possible return values:

- 0 if the entry was not the only entry in the queue
- 1 if the entry was the only entry in the queue

## **\_\_PAL\_INSQUEQ**

This function inserts a new entry after an existing entry into a quadword queue. This function must have write access to header and queue entries.

This function has the following format:

```
int __PAL_INSQUEQ (void *predecessor, void *new_entry);
```

**predecessor**

A pointer to an existing entry in the queue.

**new\_entry**

A pointer to the new entry to be inserted.

There are two possible return values:

- 0 if the entry was not the only entry in the queue
- 1 if the entry was the only entry in the queue

## **\_\_PAL\_INSQUEQ\_D**

This function inserts a new entry after an existing entry into a quadword queue deferred. This function must have write access to header and queue entries.

This function has the following format:

```
int __PAL_INSQUEQ_D (void **predecessor, void *new_entry);  
/* Deferred */
```

**predecessor**

A pointer to a pointer to the predecessor entry.

**new\_entry**

A pointer to the new entry to be inserted.

There are two possible return values:

- 0 if the entry was not the only entry in the queue
- 1 if the entry was the only entry in the queue

## **\_\_PAL\_LDQP**

This function returns the quadword-aligned memory object specified by *address*.

This function has the following format:

```
unsigned __int64 __PAL_LDQP (void *address);
```

**address**

A pointer to the quadword-aligned memory object to be returned.

If the object pointed to by *address* is not quadword-aligned, the result is unpredictable.

## **\_\_PAL\_MFPR\_XXXX**

These privileged functions return the contents of a particular processor register. The *XXXX* indicates the processor register to be read.

These functions have the following format:

```
/* AST Enable */
unsigned int __PAL_MFPR_ASTEN (void);
/* AST Summary Register */
unsigned int __PAL_MFPR_ASTSR (void);
/* Executive Stack Pointer */
void *__PAL_MFPR_ESP (void);
/* Floating-Point Enable */
int __PAL_MFPR_FEN (void);
/* Interrupt Priority Level */
int __PAL_MFPR_IPL (void);
/* Machine Check Error Summary */
int __PAL_MFPR_MCES (void);
/* Privileged Context Block Base */
void *__PAL_MFPR_PCBB (void);
/* Processor Base Register */
__int64 __PAL_MFPR_PRBR (void);
/* Page Table Base Register */
int __PAL_MFPR_PTBR (void);
/* System Control Block Base */
void *__PAL_MFPR_SCBB (void);
/* Software Interrupt Summary Register */
unsigned int __PAL_MFPR_SISR (void);
/* Supervisor Stack Pointer */
void *__PAL_MFPR_SSP (void);
/* Translation Buffer Check */
__int64 __PAL_MFPR_TBCHK (void *address);
/* User Stack Pointer */
void *__PAL_MFPR_USP (void);
/* Virtual Page Table */
```

```
void *__PAL_MFPR_VPTB (void);
/* Who Am I */
__int64 __PAL_MFPR_WHAMI (void);
```

## **\_\_PAL\_MTPR\_XXXX**

These privileged functions load a value into one of the special processor registers. The XXXX indicates the processor register to be loaded.

These functions have the following format:

```
/* AST Enable */
void __PAL_MTPR_ASTEN (unsigned int mask);
/* AST Summary Register */
void __PAL_MTPR_ASTSR (unsigned int mask);
/* Data Alignment Trap Fixup */
void __PAL_MTPR_DATFX (int value);
/* Executive Stack Pointer */
void __PAL_MTPR_ESP (void *address);
/* Floating-Point Enable */
void __PAL_MTPR_FEN (int value);
/* Interprocessor Interrupt Request */
void __PAL_MTPR_IPIR (__int64 number);
/* Interrupt Priority Level */
int __PAL_MTPR_IPL (int value);
/* Machine Check Error Summary */
void __PAL_MTPR_MCES (int value);
/* Processor Base Register */
void __PAL_MTPR_PRBR (__int64 value);
/* System Control Block Base */
void __PAL_MTPR_SCBB (void *address);
/* Software Interrupt Request Register */
void __PAL_MTPR_SIRR (int level);
/* Supervisor Stack Pointer */
void __PAL_MTPR_SSP (int *address);
/* Translation Buffer Invalidate All*/
void __PAL_MTPR_TBIA (void);
/* Translation Buffer Invalidate All Process */
void __PAL_MTPR_TBIAP (void);
/* Translation Buffer Invalidate Single */
void __PAL_MTPR_TBIS (void *address);
/* Translation Buffer Invalidate Single Data */
void __PAL_MTPR_TBISD (void *address);
/* Translation Buffer Invalidate Single Instruction */
void __PAL_MTPR_TBISI (void *address);
/* User Stack Pointer */
void __PAL_MTPR_USP (void *address);
/* Virtual Page Table */
void __PAL_MTPR_VPTB (void *address);
```

## **\_\_PAL\_PROBER**

This function checks the write accessibility of the first and last byte of the given address and length pair.

This function has the following format:

```
int __PAL_PROBER (const void *base_address, int length,
```



```
char mode);
```

**base\_address**

The pointer to the memory segment to be tested for read access.

**length**

The length of the memory segment, in bytes.

**mode**

The processor mode used for checking access.

There are two possible return values:

- 0 if both bytes are not accessible
- 1 if both bytes are accessible

**\_\_PAL\_PROBEW**

This function checks the write accessibility of the first and last byte of the given address and length pair.

This function has the following format:

```
int __PAL_PROBEW (const void *base_address, int length,  
char mode);
```

**base\_address**

The pointer to the memory segment to be tested for write access.

**length**

The length of the memory segment, in bytes.

**mode**

The processor mode used for checking access.

There are two possible return values:

- 0 if both bytes are not accessible
- 1 if both bytes are accessible

**\_\_PAL\_RD\_PS**

This function returns the Processor Status (PS).

This function has the following format:

```
unsigned __int64 __PAL_RD_PS (void);
```

**\_\_PAL\_REMQHIL**

This function removes the first entry from a longword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries.

This function has the following format:

```
int __PAL_REMQHIL (void *head, void **removed_entry);  
/* At head, interlocked */
```

**head**

A pointer to the queue header. The header must be aligned on a quadword boundary.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are four possible return values:

- -1 if the entry cannot be removed because the secondary interlock failed
- 0 if the queue was empty
- 1 if the entry was removed and the queue has remaining entries
- 2 if the entry was removed and the queue is now empty

## **\_\_PAL\_REMQHILR**

This function removes the first entry from a longword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries. All parts of the queue must be memory resident.

This function has the following format:

```
int __PAL_REMQHILR (void *head, void **removed_entry);  
/* At head, interlocked resident */
```

**head**

A pointer to the queue header. The header must be aligned on a quadword boundary.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are four possible return values:

- -1 if the entry cannot be removed because the secondary interlock failed
- 0 if the queue was empty
- 1 if the entry was removed and the queue has remaining entries
- 2 if the entry was removed and the queue is now empty

## **\_\_PAL\_REMQHIQ**

This function removes the first entry from a quadword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries.

This function has the following format:

```
int __PAL_REMQHIQ (void *head, void **removed_entry);  
/* At head, interlocked */
```

**head**

A pointer to the queue header. The header must be aligned on an octaword boundary.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are four possible return values:

- -1 if the entry cannot be removed because the secondary interlock failed
- 0 if the queue was empty
- 1 if the entry was removed and the queue has remaining entries
- 2 if the entry was removed and the queue is now empty

## **\_\_PAL\_REMQHIQR**

This function removes the first entry from a quadword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries. All parts of the queue must be memory resident.

This function has the following format:

```
int __PAL_REMQHIQR (void *head, void **removed_entry);  
/* At head, interlocked resident */
```

**head**

A pointer to the queue header. The header must be aligned on an octaword boundary.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are four possible return values:

- -1 if the entry cannot be removed because the secondary interlock failed
- 0 if the queue was empty
- 1 if the entry was removed and the queue has remaining entries
- 2 if the entry was removed and the queue is now empty

## **\_\_PAL\_REMQTIL**

This function removes the last entry from a longword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries.

This function has the following format:

```
int __PAL_REMQTIL (void *head, void **removed_entry);  
/* At tail, interlocked */
```

**head**

A pointer to the queue header. The header must be aligned on a quadword boundary.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are four possible return values:

- -1 if the entry cannot be removed because the secondary interlock failed
- 0 if the queue was empty
- 1 if the entry was removed and the queue has remaining entries
- 2 if the entry was removed and the queue is now empty

## **\_\_PAL\_REMQTILR**

This function removes the last entry from a longword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries. All parts of the queue must be memory resident.

This function has the following format:

```
int __PAL_REMQTILR (void *head, void **removed_entry);  
/* At tail, interlocked resident */
```

**head**

A pointer to the queue header. The header must be aligned on a quadword boundary.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are four possible return values:

- -1 if the entry cannot be removed because the secondary interlock failed
- 0 if the queue was empty
- 1 if the entry was removed and the queue has remaining entries
- 2 if the entry was removed and the queue is now empty

## **\_\_PAL\_REMQTIQ**

This function removes the last entry from a quadword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries.

This function has the following format:

```
int __PAL_REMQTIQ (void *head, void **removed_entry);  
/* At tail, interlocked */
```

**head**

A pointer to the queue header. The header must be aligned on an octaword boundary.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are four possible return values:

- -1 if the entry cannot be removed because the secondary interlock failed
- 0 if the queue was empty
- 1 if the entry was removed and the queue has remaining entries
- 2 if the entry was removed and the queue is now empty

## **\_\_PAL\_REMQTIQR**

This function removes the last entry from a quadword queue in an indivisible manner. This operation is interlocked against similar operations by other preprocessors or devices in the system. This function must have write access to the header and queue entries. All parts of the queue must be memory resident.

This function has the following format:

```
int __PAL_REMQTIQR (void *head, void **removed_entry);  
/* At tail, interlocked resident */
```

**head**

A pointer to the queue header. The header must be aligned on an octaword boundary.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are four possible return values:

- -1 if the entry cannot be removed because the secondary interlock failed
- 0 if the queue was empty
- 1 if the entry was removed and the queue has remaining entries
- 2 if the entry was removed and the queue is now empty

## **\_\_PAL\_REMQUEL**

This function removes an entry from a longword queue. This function must have write access to header and queue entries.

This function has the following format:

```
int  _PAL_REMQUEL (void *entry, void **removed_entry);
```

**entry**

A pointer to the queue entry to be removed.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are three possible return values:

- -1 if the queue was empty
- 0 if the entry was removed and the queue is now empty
- 1 if the entry was removed and the queue has remaining entries

## **\_\_PAL\_REMQUEL\_D**

This function removes an entry from a longword queue deferred. This function must have write access to header and queue entries.

This function has the following format:

```
int  __PAL_REMQUEL_D (void **entry, void **removed_entry);  
/* Deferred */
```

**entry**

A pointer to a pointer to the queue entry to be removed.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are three possible return values:

- -1 if the queue was empty
- 0 if the entry was removed and the queue is now empty
- 1 if the entry was removed and the queue has remaining entries

## **\_\_PAL\_REMQUEQ**

This function removes an entry from a quadword queue. This function must have write access to header and queue entries.

This function has the following format:

```
int __PAL_REMQUEQ (void *entry, void **removed_entry);
```

**entry**

A pointer to the queue entry to be removed.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are three possible return values:

- -1 if the queue was empty
- 0 if the entry was removed and the queue is now empty
- 1 if the entry was removed and the queue has remaining entries

**\_\_PAL\_REMQUEQ\_D**

This function removes an entry from a quadword queue deferred. This function must have write access to header and queue entries.

This function has the following format:

```
int __PAL_REMQUEQ_D (void **entry, void **removed_entry);  
/* Deferred */
```

**entry**

A pointer to a pointer to the queue entry to be removed.

**removed\_entry**

A pointer to the address of the entry removed from the queue.

There are three possible return values:

- -1 if the queue was empty
- 0 if the entry was removed and the queue is now empty
- 1 if the entry was removed and the queue has remaining entries

**\_\_PAL\_STQP**

This function writes the quadword *value* to the memory location pointed to by *address*.

This function has the following format:

```
void __PAL_STQP (void *address, unsigned __int64 value);
```

**address**

Memory location to be written to.

**value**

Quadword value to be stored.

If the location pointed to by *address* is not quadword-aligned, the result is unpredictable.

## **\_\_PAL\_SWASTEN**

This function swaps the previous state of the Asynchronous System Trap (AST) enable bit for the new state. The new state is supplied in bit 0 of *new\_state\_mask*. The previous state is returned, zero-extended.

A check is made to determine if an AST is pending. If the enabling conditions are present for an AST at the completion of this instruction, the AST occurs before the next instruction.

This function has the following format:

```
unsigned int  __PAL_SWASTEN (int new_state_mask);
```

**new\_state\_mask**

An integer whose 0 bit is the new state of the AST enable bit.

## **\_\_PAL\_SWPCTX**

This function returns ownership of the data structure that contains the current hardware privileged context (the HWPCB) to the operating system and passes ownership of the new HWPCB to the processor.

This function has the following format:

```
void  __PAL_SWPCTX (void *address);
```

**address**

A pointer to the new HWPCB.

## **\_\_PAL\_WR\_PS\_SW**

This function writes the low-order three bits of *mask* into the Processor Status software field (PS<SW>).

This function has the following format:

```
void  __PAL_WR_PS_SW (int mask);
```

**mask**

An integer whose low-order three bits are written into PS<SW>.

## **B.1.4. Other Builtins**

### **Absolute Value ( \_\_ABS)**

The `__ABS` built-in is functionally equivalent to its counterpart, `abs`, in the standard header file `<stdlib.h>`.



Its format is also the same:

```
#include <stdlib.h>
int __ABS (int x);
```

This built-in function does, however, offer performance improvements because there is less call overhead associated with its use.

If you include `<stdlib.h>`, the built-in function is automatically used for all occurrences of `abs`. To disable the built-in function, use `#undef abs`.

## Acquire and Release Longword Semaphore (**\_\_ACQUIRE\_SEM\_LONG, \_\_RELEASE\_SEM\_LONG**)

The `__ACQUIRE_SEM_LONG` and `__RELEASE_SEM_LONG` functions provide a counted semaphore capability where the positive value of a longword is interpreted as the number of resources available.

The `__ACQUIRE_SEM_LONG` function loops until the longword has a positive value and then decrements it within a load-locked/store-conditional sequence; it then issues a memory barrier. This function returns 1 if the resource count was successfully decremented within the specified number of retries, and 0 otherwise. With no explicit retry count, the function does not return until it succeeds.

The `__RELEASE_SEM_LONG` function issues a memory barrier and then does an `__ATOMIC_INCREMENT_LONG` on the longword.

The `__ACQUIRE_SEM_LONG` function has the following formats:

```
int __ACQUIRE_SEM_LONG (volatile void *address);
int __ACQUIRE_SEM_LONG_RETRY (volatile void *address, int retry);
```

The `__RELEASE_SEM_LONG` function has the following format:

```
int __RELEASE_SEM_LONG (volatile void *address);
```

**address**

The longword-aligned address of the resource count.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the longword.

## Add Aligned Word Interlocked ( **\_\_ADAWI**)

The `__ADAWI` function adds its source operand to the destination. This function is interlocked against similar operations by other processors or devices in the system.

This function has the following format:

```
int __ADAWI (short src, short *dest);
```

**src**

The value to be added to the destination.

**dest**

A pointer to the destination. The destination must be aligned on a word boundary.

The `__ADAWI` function returns a simulated VAX processor status longword (PSL).

## Add Atomic Longword ( `__ADD_ATOMIC_LONG` )

The `__ADD_ATOMIC_LONG` function adds the specified expression to the longword data segment pointed to by the address parameter within a load-locked/store-conditional code sequence.

This function has the following format:

```
int __ADD_ATOMIC_LONG int fnc(void *, int, ...);
```

**address**

The address of the data segment.

**expression**

An integer expression.

...

An optional retry count of type `int`. If specified, the retry count indicates the number of times the operation is attempted. If the operation cannot be performed successfully in the specified number of retries, a value of 0 is returned.

A value of 1 is returned upon successful completion.

## Add Atomic Quadword ( `__ADD_ATOMIC_QUAD` )

The `__ADD_ATOMIC_QUAD` function adds the specified expression to the quadword data segment pointed to by the address parameter within a load-locked/store-conditional code sequence.

This function has the following format:

```
int __ADD_ATOMIC_QUAD (void *address, int expression, ...);
```

**address**

The address of the data segment.

**expression**

An integer expression.

...

An optional retry count of type `int`. If specified, the retry count indicates the number of times the operation is attempted. If the operation cannot be performed successfully in the specified number of retries, a value of 0 is returned.

A value of 1 is returned upon successful completion.

## AND Atomic Longword ( **\_\_AND\_ATOMIC\_LONG** )

The **\_\_AND\_ATOMIC\_LONG** function performs a bit-wise or arithmetic AND of the specified expression with the aligned longword pointed to by the address parameter within a load-locked/store-conditional code sequence.

This function has the following format:

```
int __AND_ATOMIC_LONG (void *address, int expression, ...);
```

**address**

The longword-aligned address of the data segment.

**expression**

An integer expression.

...

An optional retry count of type `int`. If specified, the retry count indicates the number of times the operation is attempted (which will be at least once, even if the count argument is 0). If the operation cannot be performed successfully in the specified number of retries, a value of 0 is returned.

A value of 1 is returned upon successful completion.

## AND Atomic Quadword ( **\_\_AND\_ATOMIC\_QUAD** )

The **\_\_AND\_ATOMIC\_QUAD** function performs a bit-wise or arithmetic AND of the specified expression with the aligned quadword pointed to by the address parameter within a load-locked/store-conditional code sequence.

This function has the following format:

```
int __AND_ATOMIC_QUAD (void *address, int expression, ...);
```

**address**

The address of the aligned quadword.

**expression**

An integer expression.

...

An optional retry count of type `int`. If specified, the retry count indicates the number of times the operation is attempted (which will be at least once, even if the count argument is 0). If the operation cannot be performed successfully in the specified number of retries, a value of 0 is returned.

A value of 1 is returned upon successful completion.

## Atomic Add Longword ( **\_\_ATOMIC\_ADD\_LONG** )

The `__ATOMIC_ADD_LONG` function adds the specified expression to the aligned longword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the longword before the addition was performed.

This function has one of the following formats:

```
int __ATOMIC_ADD_LONG (volatile void *address,
int expression);

int __ATOMIC_ADD_LONG_RETRY (volatile void *address,
int expression, int retry,
int *status);
```

**address**

The longword-aligned address of the data segment.

**expression**

An integer expression.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the longword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Atomic Add Quadword (`__ATOMIC_ADD_QUAD`)

The `__ATOMIC_ADD_QUAD` function adds the specified expression to the aligned quadword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the quadword before the addition was performed.

This function has one of the following formats:

```
int __ATOMIC_ADD_QUAD (volatile void *address,
int expression);

int __ATOMIC_ADD_QUAD_RETRY (volatile void *address,
int expression, int retry,
int *status);
```

**address**

The quadword-aligned address of the data segment.

**expression**

An integer expression.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the quadword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Atomic AND Longword (`__ATOMIC_AND_LONG`)

The `__ATOMIC_AND_LONG` function performs a bit-wise or arithmetic AND of the specified expression with the aligned longword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the longword before the operation was performed.

This function has one of the following formats:

```
int __ATOMIC_AND_LONG (volatile void *address,  
int expression);
```

```
int __ATOMIC_AND_LONG_RETRY (volatile void *address,  
int expression, int retry,  
int *status);
```

**address**

The longword-aligned address of the data segment.

**expression**

An integer expression.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the longword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Atomic AND Quadword (`__ATOMIC_AND_QUAD`)

The `__ATOMIC_AND_QUAD` function performs a bit-wise or arithmetic AND of the specified expression with the aligned quadword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the quadword before the operation was performed.

This function has one of the following formats:

```
int __ATOMIC_AND_QUAD (volatile void *address,  
int expression);
```

```
int __ATOMIC_AND_QUAD_RETRY (volatile void *address,  
int expression, int retry,  
int *status);
```

**address**

The quadword-aligned address of the data segment.

**expression**

An integer expression.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the quadword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Atomic OR Longword (`__ATOMIC_OR_LONG`)

The `__ATOMIC_OR_LONG` function performs a bit-wise or arithmetic OR of the specified expression with the aligned longword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the longword before the operation was performed.

This function has one of the following formats:

```
int  __ATOMIC_OR_LONG (volatile void *address, int expression);

int  __ATOMIC_OR_LONG_RETRY (volatile void *address, int expression,
                             int retry, int *status);
```

**address**

The longword-aligned address of the data segment.

**expression**

An integer expression.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the longword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Atomic OR Quadword (`__ATOMIC_OR_QUAD`)

The `__ATOMIC_OR_QUAD` function performs a bit-wise or arithmetic OR of the specified expression with the aligned quadword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the quadword before the operation was performed.

This function has one of the following formats:

```
int  __ATOMIC_OR_QUAD (volatile void *address,
int  expression);

int  __ATOMIC_OR_QUAD_RETRY (volatile void *address,
int  expression,
int  retry, int *status);
```

**address**

The quadword-aligned address of the data segment.

**expression**

An integer expression.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the quadword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Atomic Increment Longword (`__ATOMIC_INCREMENT_LONG`)

The `__ATOMIC_INCREMENT_LONG` function increments by 1 the aligned longword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the longword before the operation was performed.

This function has the following formats:

```
int  __ATOMIC_INCREMENT_LONG (volatile void *address);

int  __ATOMIC_INCREMENT_LONG_RETRY (volatile void *address,
int  retry, int *status);
```

**address**

The longword-aligned address of the data segment.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the quadword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Atomic Increment Quadword (`__ATOMIC_INCREMENT_QUAD`)

The `__ATOMIC_INCREMENT_QUAD` function increments by 1 the aligned quadword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the quadword before the operation was performed.

This function has the following formats:

```
int  __ATOMIC_INCREMENT_QUAD (volatile void *address);

__int64 __ATOMIC_INCREMENT_QUAD (volatile void *address,
int  retry, int  *status);
```

### **address**

The quadword-aligned address of the data segment.

### **retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the quadword.

### **status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Atomic Decrement Longword (`__ATOMIC_DECREMENT_LONG`)

The `__ATOMIC_DECREMENT_LONG` function decrements by 1 the aligned longword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the longword before the operation was performed.

This function has the following formats:

```
int  __ATOMIC_DECREMENT_LONG (volatile void *address);

int  __ATOMIC_DECREMENT_LONG_RETRY (volatile void *address, int  retry, int
    *status);
```

### **address**

The longword-aligned address of the data segment.

### **retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the quadword.

### **status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.



## Atomic Decrement Quadword (`__ATOMIC_DECREMENT_QUAD`)

The `__ATOMIC_DECREMENT_QUAD` function decrements by 1 the aligned quadword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the quadword before the operation was performed.

This function has the following formats:

```
int __ATOMIC_DECREMENT_QUAD (volatile void *address);
```

```
__int64 __ATOMIC_DECREMENT_QUAD_RETRY (volatile void *address, int retry,  
int *status);
```

### **address**

The quadword-aligned address of the data segment.

### **retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the quadword.

### **status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Atomic Exchange Longword (`__ATOMIC_EXCH_LONG`)

The `__ATOMIC_EXCH_LONG` function stores the value of the specified expression into the aligned longword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the longword before the operation was performed.

This function has one of the following formats:

```
int __ATOMIC_EXCH_LONG (volatile void *address,  
int expression);
```

```
int __ATOMIC_EXCH_LONG_RETRY (volatile void *address,  
int expression,  
int retry, int *status);
```

### **address**

The longword-aligned address of the data segment.

### **expression**

An integer expression.

### **retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the longword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

**Atomic Exchange Quadword ( \_\_ATOMIC\_EXCH\_QUAD)**

The \_\_ATOMIC\_EXCH\_QUAD function stores the value of the specified expression into the aligned quadword pointed to by the *address* parameter within a load-locked/store-conditional code sequence and returns the value of the quadword before the operation was performed.

This function has one of the following formats:

```
int __ATOMIC_EXCH_QUAD (volatile void *address,
int expression);

int __ATOMIC_EXCH_QUAD_RETRY (volatile void *address,
int expression, int retry,
int *status);
```

**address**

The quadword-aligned address of the data segment.

**expression**

An integer expression.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the quadword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

**Allocate Bytes from Stack ( \_\_ALLOC)**

The \_\_ALLOC function allocates *n* bytes from the stack.

This function has the following format:

```
void *__ALLOC (unsigned int n);
```

**n**

The number of bytes to be allocated.

A pointer to the allocated memory is returned.

**Single-Precision, Floating-Point Arithmetic Built-in Functions**

The following built-in functions provide single-precision, floating-point chopped arithmetic:

<code>__ADDF_C</code>	<code>__ADDS_C</code>	<code>__SUBF_C</code>	<code>__SUBS_C</code>
<code>__MULF_C</code>	<code>__MULS_C</code>	<code>__DIVF_C</code>	<code>__DIVS_C</code>

They have the following format:

```
float __op{F,S}_C (float operand1, float operand2);
```

Where *op* is one of ADD, SUB, MUL, DIV, and {F,S} represents VAX or IEEE floating-point arithmetic.

The result of the arithmetic operation is returned.

## Double-Precision, Floating-Point Arithmetic Built-in Functions

The following built-in functions provide double-precision, floating-point chopped arithmetic:

<code>__ADDG_C</code>	<code>__ADDT_C</code>	<code>__SUBG_C</code>	<code>__SUBT_C</code>
<code>__MULG_C</code>	<code>__MULT_C</code>	<code>__DIVG_C</code>	<code>__DIVT_C</code>

They have the following format:

```
double __op{G,T}_C (double operand1, double operand2);
```

Where *op* is one of ADD, SUB, MUL, DIV, and {G,T} represents VAX or IEEE floating-point arithmetic.

The result of the arithmetic operation is returned.

## Copy Sign Built-in Functions

Built-in functions are provided to copy selected portions of single- and double-precision, floating-point numbers.

These built-in functions have the following format:

```
float __CPYSF (float operand1, float operand2);
double __CPYS (double operand1, double operand2);
```

```
float __CPYSNF (float operand1, float operand2);
double __CPYSN (double operand1, double operand2);
```

```
float __CPYSEF (float operand1, float operand2);
double __CPYSE (double operand1, double operand2);
```

The copy sign built-in functions (`__CPYSF` and `__CPYS`) fetch the sign bit in *operand1*, concatenate it with the exponent and fraction bits from *operand2*, and return the result.

The copy sign negate built-in functions (`__CPYSNF` and `__CPYSN`) fetch the sign bit in *operand1*, complement it, concatenate it with the exponent and fraction bits from *operand2*, and return the result.

The copy sign exponent built-in functions (`__CPYSEF` and `__CPYSE`) fetch the sign and exponent bits from *operand1*, concatenate them with the fraction bits from *operand2*, and return the result.

## Compare Store Longword ( `__CMP_STORE_LONG` )

The `__CMP_STORE_LONG` function has the following format:

```
int __CMP_STORE_LONG (void *source, int old_value,
int new_value, void *dest);
```

This function compares the value pointed to by *source* with the longword *old\_value*. If they are equal, the longword *new\_value* is stored into the value pointed to by *dest*. The comparison is within a load-locked/store-conditional code sequence.

The function returns 0 if the two values are unequal, if *source* and *dest* are not in the same 16-byte lock region, or if some other process accessed the 16-byte lock region before *new\_value* could be stored. The function returns 1 if the two values are equal and *new\_value* was stored atomically.

## Compare Store Quadword ( `__CMP_STORE_QUAD` )

The `__CMP_STORE_QUAD` function has the following format:

```
int __CMP_STORE_QUAD (void *source, __int64 old_value,
__int64 new_value, void *dest);
```

This function compares the value pointed to by *source* with the quadword *old\_value*. If they are equal, the quadword *new\_value* is stored into the value pointed to by *dest*. The comparison is within a load-locked/store-conditional code sequence.

The function returns 0 if the two values are unequal, if *source* and *dest* are not in the same 16-byte lock region, or if some other process accessed the 16-byte lock region before *new\_value* could be stored. The function returns 1 if the two values are equal and *new\_value* was stored atomically.

## Cosine ( `__COS` )

The `__COS` built-in function is functionally equivalent to its counterpart, `cos`, in the standard header file `<math.h>`.

Its format is also the same:

```
#include <math.h>
double __COS (double x);
```

**x**

A radian value.

This built-in function does, however, offer performance improvements because there is less call overhead associated with its use.

If you include `<math.h>`, the built-in function is automatically used for all occurrences of `cos`. To disable the built-in function, use `#undef cos`.

## Convert G\_Floating to F\_Floating Chopped ( `__CVTGF_C` )

The `__CVTGF_C` function converts a double-precision, VAX G\_floating-point number to a single-precision, VAX F\_floating-point number. This conversion chops to single-precision; then the 8-bit exponent range is checked for overflow or underflow.

This function has the following format:

```
float  __CVTGF_C (double operand);
```

**operand**

A double-precision, VAX floating-point number.

**Convert G-Floating to Quadword ( \_\_CVTGQ)**

The \_\_CVTGQ function rounds a double-precision, VAX floating-point number to a 64-bit integer value and returns the result.

This function has the following format:

```
__int64  __CVTGQ (double operand);
```

**operand**

A double-precision, VAX floating-point number.

**Convert IEEE T\_Floating to IEEE S\_Floating Chopped ( \_\_CVTTS\_C)**

The \_\_CVTTS\_C function converts a double-precision, IEEE T\_floating-point number to a single-precision, IEEE S\_floating-point number. This conversion chops to single-precision; then the 8-bit exponent range is checked for overflow or underflow.

This function has the following format:

```
float  __CVTTS_C (double operand);
```

**operand**

A double-precision, IEEE floating-point number.

**Convert IEEE T-Floating to Quadword ( \_\_CVTTQ)**

The \_\_CVTTQ function rounds a double-precision, IEEE-floating-point number to a 64-bit integer value and returns the result.

This function has the following format:

```
__int64  __CVTTQ (double operand);
```

**operand**

A double-precision, IEEE T-floating-point number.

**Floating-Point Absolute Value ( \_\_FABS)**

The \_\_FABS built-in function is functionally equivalent to its counterpart, `fabs`, in the standard header file `<math.h>`.

Its format is also the same:

```
#include <math.h>
double@@__FABS (double x);
```

**x**

A floating-point number.

This built-in function does, however, offer performance improvements because there is no call overhead associated with its use.

If you include `<math.h>`, the built-in function is automatically used for all occurrences of `fab`. To disable the built-in function, use `#undef fab`.

## Test for Bit Clear then Clear Bit Interlocked (**\_\_INTERLOCKED\_TESTBITCC\_QUAD**)

The `__INTERLOCKED_TESTBITCC_QUAD` function performs the following functions in interlocked fashion:

1. Returns the complement of the specified bit before being cleared.
2. Clears the bit.

This function has the following formats:

```
int __INTERLOCKED_TESTBITCC_QUAD (volatile void *address,
    int bit_position);

int __INTERLOCKED_TESTBITCC_QUAD_RETRY (volatile void *address,
    int bit_position, int retry, int *status);
```

### **address**

The quadword-aligned base address of the bit field.

### **bit\_position**

The position within the field of the bit that you want cleared, in the range of 0 to 63.

### **retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the `retry` argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the quadword.

### **status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

## Test for Bit Set Then Set Bit Interlocked (**\_\_INTERLOCKED\_TESTBITSS\_QUAD**)

The `__INTERLOCKED_TESTBITSS_QUAD` function performs the following functions in interlocked fashion:

1. Returns the value of the specified bit before being set.
2. Sets the bit.

This function has the following formats:

```
int  __INTERLOCKED_TESTBITSS_QUAD (volatile void *address,
    int bit_position);

int  __INTERLOCKED_TESTBITSS_QUAD_RETRY (volatile void *address,
    int expression, int retry, int *status);
```

**address**

The quadword-aligned base address of the bit field.

**bit\_position**

The position within the field of the bit that you want cleared, in the range of 0 to 63.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the longword.

**status**

A pointer to an integer that is set to 0 if the operation did not succeed within the specified number of retries, and set to 1 if the operation succeeded.

**leadz**

The `_leadz` built-in function returns the number of leading zeroes (starting at the most significant bit position) in its argument. For example, `_leadz(1)` returns 63, and `_leadz(0)` returns 64.

This function has the following format:

```
__int64 _leadz (unsigned __int64);
```

**Lock and Unlock Longword (\_\_LOCK\_LONG, \_\_UNLOCK\_LONG)**

The `__LOCK_LONG` and `__UNLOCK_LONG` functions provide a binary spinlock capability based on the low-order bit of a longword.

The `__LOCK_LONG` function executes in a loop waiting for the bit to be cleared and then sets it within a load-locked/store-conditional sequence; it then issues a memory barrier. The `__UNLOCK_LONG` function issues a memory barrier and then zeroes the longword.

The `__LOCK_LONG_RETRY` function returns 1 if the lock was acquired in the specified number of retries and 0 if the lock was not acquired.

The `__LOCK_LONG` function has the following formats:

```
int  __LOCK_LONG (volatile void *address);

int  __LOCK_LONG_RETRY (volatile void *address, int retry);
```

The `__UNLOCK_LONG` function has the following format:

```
int  __UNLOCK_LONG (volatile void *address);
```

**address**

The quadword-aligned address of the longword used for the lock.

**retry**

A retry count of type `int` that indicates the number of times the operation is attempted (which is at least once, even if the *retry* argument is 0). If the operation cannot be performed successfully in the specified number of retries, the function returns without updating the longword.

**Longword Absolute Value ( \_\_LABS)**

The `__LABS` built-in function is functionally equivalent to its counterpart, `labs`, in the standard header file `<stdlib.h>`.

Its format is also the same:

```
#include <stdlib.h>
long int@@__LABS (long int x);
```

**x**

An integer.

This built-in function does, however, offer performance improvements because there is less call overhead associated with its use.

If you include `<stdlib.h>`, the built-in function is automatically used for all occurrences of `labs`. To disable the built-in function, use `#undef labs`.

**Memory Barrier ( \_\_MB)**

The `__MB` function directs the compiler to generate a memory barrier instruction.

This function has the following format:

```
void __MB (void);
```

**Memory Copy and Set Functions ( \_\_MEMCPY, \_\_MEMMOVE, \_\_MEMSET)**

The `__MEMCPY`, `__MEMMOVE`, and `__MEMSET` built-in functions are functionally equivalent to their counterparts in the standard header file `<string.h>`.

Their format is also the same:

```
#include <string.h>

void *__MEMCPY (void *s1, const void *s2, size_t size);

void *__MEMMOVE (void *s1, const void *s2, size_t size);

void *__MEMSET (void *s, int value, size_t size);
```

These built-in functions do, however, offer performance improvements because there is less call overhead associated with their use.



If you include `<string.h>`, the built-in functions are automatically used for all occurrences of `memcpy`, `memmove`, and `memset`. To disable the built-in functions, use `#undef memcpy`, `#undef memmove`, and `#undef memset`.

## **`_popcnt`**

The `_popcnt` built-in function returns the number of "1" bits (0 to 64) in its argument. For example, `_popcnt(12)` returns 2.

This function has the following format:

```
__int64 _popcnt (unsigned __int64);
```

## **`_poppar`**

The `_poppar` built-in function returns 1 if the number of "1" bits in its argument is odd; otherwise it returns 0. For example, `_poppar(12)` returns 0.

This function has the following format:

```
__int64 _poppar (unsigned __int64);
```

## **Read Process Cycle Counter ( `__RPCC` )**

The `__RPCC` function reads the current process cycle counter.

This function has the following format:

```
__int64 __RPCC (void);
```

## **Sine ( `__SIN` )**

The `__SIN` built-in function is functionally equivalent to its counterpart in the standard header file `<math.h>`.

Its format is also the same:

```
#include <math.h>
double __SIN (double x);
```

**x**

A radian value.

This built-in function does, however, offer performance improvements because there is less call overhead associated with its use.

If you include `<math.h>`, the built-in function is used automatically for all occurrences of `sin`. To disable the built-in function, use `#undef sin`.

## **Test for Bit Clear then Clear Bit Interlocked ( `__TESTBITCCI` )**

The `__TESTBITCCI` function performs the following operations in interlocked fashion:

- Returns the complement of the specified bit before being cleared

- Clears the bit

This function has the following format:

```
int __TESTBITCCI (void *address, int position, ...);
```

**address**

The base address of the field.

**position**

The position within the field of the bit that you want cleared.

...

An optional retry count of type `int`. If specified, the retry count indicates the number of times the operation is attempted. If the operation cannot be performed successfully in the specified number of retries, a value of 0 is returned.

## Test for Bit Set then Set Bit Interlocked ( \_\_TESTBITSSI)

The `__TESTBITSSI` function performs the following operations in interlocked fashion:

- Returns the value of the specified bit before being set
- Sets the bit

This function has the following format:

```
int __TESTBITSSI (void *address, int position, ...);
```

**address**

The base address of the field.

**position**

The position within the field of the bit that you want set.

...

An optional retry count of type `int`. If specified, the retry count indicates the number of times the operation is attempted. If the operation cannot be performed successfully in the specified number of retries, a value of 0 is returned.

## **\_trailz**

The `_trailz` built-in function returns the number of trailing zeros (counting after the least significant set bit to the least significant bit position) in its argument. For example, `_trailz(2)` returns 1, and `_trailz(0)` returns 64.

This function has the following format:

```
__int64 _trailz (unsigned __int64);
```

## Trap Barrier Instruction ( \_\_TRAPB)

The `__TRAPB` function allows software to guarantee that, in a pipeline implementation, all previous arithmetic instructions will be completed without incurring any arithmetic traps before any instructions after the `TRAPB` instruction are issued.

This function has the following format:

```
void __TRAPB (void);
```

## Unsigned Quadword Multiply High ( `__UMULH` )

The `__UMULH` function performs a quadword multiply high instruction.

This function has the following format:

```
unsigned __int64 __UMULH (unsigned __int64 operand1, unsigned  
__int64 operand2);
```

### **operand1**

A 64-bit unsigned integer.

### **operand2**

A 64-bit unsigned integer.

The two operands are multiplied as unsigned integers to produce a 128-bit result. The high order 64-bits are returned.

## B.2. Built-In Functions for IA-64 Systems (IA-64 only)

The VSI C++ built-in functions available on OpenVMS Alpha systems are also available on IA-64 systems, with some differences, as described in this section. This section also describes built-in functions that are specific to IA-64 systems.

### B.2.1. Builtin Differences on IA-64 Systems

The `<builtins.h>` header file contains comments noting which built-in functions are not available or are not the preferred form for IA-64 systems. The compiler issues diagnostics where using a different built-in function for IA-64 systems would be preferable.

---

#### Note

The comments in `<builtins.h>` reflect only what is explicitly present in that header file itself, and in the compiler implementation. You should also consult the content and comments in `<pal_builtins.h>` to determine more accurately what functionality is effectively provided by including `<builtins.h>`. For example, if a program explicitly declares one of the Alpha built-in functions and invokes it without having included `<builtins.h>`, the compiler might issue the `BIFNOTAVAIL` error message, regardless of whether or not the function is available through a system service. If the compilation does include `<builtins.h>`, and `BIFNOTAVAIL` is issued, then either there is no support at all for the built-in function or a new version of `<pal_builtins.h>` is needed.

---

Here is a summary of these differences on IA-64 systems:

- There is no support for the `asm`, `fasm`, and `dasm` intrinsics (declared in the `<c_asm.h>` header file).
- The functionality provided by the special-case treatment of R26 in an Alpha system `asm`, as in `asm( "MOV R26, R0" )`, is provided by a new built-in function for IA-64 systems:

```
__int64 __RETURN_ADDRESS(void);
```

This built-in function produces the address to which the function containing the built-in call will return (the value of R26 on entry to the function on Alpha systems; the value of B0 on entry to the function on IA-64 systems). This built-in function cannot be used within a function specified to use nonstandard linkage.

- The only PAL function calls implemented as built-in functions within the compiler are the 24 queue-manipulation builtins. The queue manipulation builtins generate calls to new OpenVMS system services `SYSS$<name>`, where `<name>` is the name of the builtin with the leading underscores removed.

Any other OpenVMS PAL calls are supported through macros defined in the `<pal_builtins.h>` header file included in the `<builtins.h>` header file. Typically, the macros in `<pal_builtins.h>` transform an invocation of an Alpha system builtin into a call to a system service that performs the equivalent function on an IA-64 system. Two notable exceptions are `__PAL_GENTRAP` and `__PAL_BUGCHK`, which instead invoke the IA-64 specific compiler builtin `__break2`.

- There is no support for the various floating-point built-in functions used by the OpenVMS math library (for example, operations with chopped rounding and conversions).
- For most built-in functions that take a retry count, the compiler issues an error message. Such builtins must be replaced with the corresponding builtin that does not have a retry count. This is necessary because the retry behavior allowed by Alpha load-locked/store-conditional sequences does not exist on IA-64 systems. There are two exceptions to this: `__LOCK_LONG_RETRY` and `__ACQUIRE_SEM_LONG_RETRY`; in these cases, the retry behavior involves comparisons of data values, not just load-locked/store-conditional.
- The `__CMP_STORE_LONG` and `__CMP_STORE_QUAD` built-in functions produce an error message, and must be replaced with the new `__CMP_SWAP_LONG` and `__CMP_SWAP_QUAD` built-in functions.

## B.2.2. Built-in Functions Specific to IA-64 Systems

The `<builtins.h>` header file contains a section at the top conditionalized to just `__ia64` with the support for built-in functions specific to IA-64 systems. This includes macro definitions for all of the registers that can be specified to the `__getReg`, `__setReg`, `__getIndReg`, and `__setIndReg` built-in functions. Parameters that are `const`-qualified require an argument that is a compile-time constant.

The following sections describe the VSI C++ built-in functions available on OpenVMS IA-64 systems.

### Get Hardware Register Value ( `__getReg` )

The `__getReg` function gets the value from a hardware register based on the register index specified. This function produces a corresponding `mov = r` instruction.

This function has the following format:

```
unsigned __int64 __getReg (const int whichReg);
```

### **whichReg**

The index of the hardware register from which the value is obtained. The `__getReg` and `__setReg` functions can access the following registers:

Register Name	<i>whichReg</i>
<code>_IA64_REG_IP</code>	1016
<code>_IA64_REG_PSR</code>	1019
<code>_IA64_REG_PSR_L</code>	1019

#### General Integer Registers:

Register Name	<i>whichReg</i>
<code>_IA64_REG_GP</code>	1025
<code>_IA64_REG_SP</code>	1036
<code>_IA64_REG_TP</code>	1037

#### Application Registers:

Register Name	<i>whichReg</i>
<code>_IA64_REG_AR_KR0</code>	3072
<code>_IA64_REG_AR_KR1</code>	3073
<code>_IA64_REG_AR_KR2</code>	3074
<code>_IA64_REG_AR_KR3</code>	3075
<code>_IA64_REG_AR_KR4</code>	3076
<code>_IA64_REG_AR_KR5</code>	3077
<code>_IA64_REG_AR_KR6</code>	3078
<code>_IA64_REG_AR_KR7</code>	3079
<code>_IA64_REG_AR_RSC</code>	3088
<code>_IA64_REG_AR_BSP</code>	3089
<code>_IA64_REG_AR_BSPSTORE</code>	3090
<code>_IA64_REG_AR_RNAT</code>	3091
<code>_IA64_REG_AR_FCR</code>	3093
<code>_IA64_REG_AR_EFLAG</code>	3096
<code>_IA64_REG_AR_CSD</code>	3097
<code>_IA64_REG_AR_SSD</code>	3098
<code>_IA64_REG_AR_CFLAG</code>	3099
<code>_IA64_REG_AR_FSR</code>	3100
<code>_IA64_REG_AR_FIR</code>	3101
<code>_IA64_REG_AR_FDR</code>	3102
<code>_IA64_REG_AR_CCV</code>	3104
<code>_IA64_REG_AR_UNAT</code>	3108
<code>_IA64_REG_AR_FPSR</code>	3112
<code>_IA64_REG_AR_ITC</code>	3116
<code>_IA64_REG_AR_PFS</code>	3136
<code>_IA64_REG_AR_LC</code>	3137
<code>_IA64_REG_AR_EC</code>	3138

#### Control Registers:

Register Name	<i>whichReg</i>
<code>_IA64_REG_CR_DCR</code>	4096
<code>_IA64_REG_CR_ITM</code>	4097
<code>_IA64_REG_CR_IVA</code>	4098
<code>_IA64_REG_CR_PTA</code>	4104
<code>_IA64_REG_CR_IPSR</code>	4112

<code>__IA64_REG_CR_ISR</code>	4113
<code>__IA64_REG_CR_IIP</code>	4115
<code>__IA64_REG_CR_IFA</code>	4116
<code>__IA64_REG_CR_ITIR</code>	4117
<code>__IA64_REG_CR_IIPA</code>	4118
<code>__IA64_REG_CR_IFS</code>	4119
<code>__IA64_REG_CR_IIM</code>	4120
<code>__IA64_REG_CR_IHA</code>	4121
<code>__IA64_REG_CR_LID</code>	4160
<code>__IA64_REG_CR_IVR</code>	4161 *
<code>__IA64_REG_CR_TPR</code>	4162
<code>__IA64_REG_CR_EOI</code>	4163
<code>__IA64_REG_CR_IRR0</code>	4164 *
<code>__IA64_REG_CR_IRR1</code>	4165 *
<code>__IA64_REG_CR_IRR2</code>	4166 *
<code>__IA64_REG_CR_IRR3</code>	4167 *
<code>__IA64_REG_CR_ITV</code>	4168
<code>__IA64_REG_CR_PMV</code>	4169
<code>__IA64_REG_CR_CMCV</code>	4170
<code>__IA64_REG_CR_LRR0</code>	4176
<code>__IA64_REG_CR_LRR1</code>	4177

\* `getReg` only

## Set Hardware Register Value ( `__setReg` )

The `__setReg` function sets the value for a hardware register based on the register index specified. This function produces a corresponding `mov = r` instruction.

This function has the following format:

```
void __setReg (const int whichReg, unsigned __int64 value);
```

### **`whichReg`**

The index of the hardware register whose value is being set. See the `__getReg` functions for the list of registers that can be accessed.

### **`value`**

The value to which the register is set.

## Get Index Register Value ( `__getIndReg` )

The `__getIndReg` function returns the value of an indexed register. The function accesses a register (*index*) in a register file (*whichIndReg*) of 64-bit registers.

This function has the following format:

```
unsigned __int64 __getIndReg  
(const int whichIndReg, __int64 index);
```

### **`whichIndReg`**

The register file.

### **`index`**

The index in the register file of the hardware register whose value is being requested. See the `__getReg` functions for the list of registers that can be accessed.

Indirect Registers for `getIndReg` and `setIndReg`:

Register Name	<i>whichReg</i>
<code>__IA64_REG_INDR_CPUID</code>	9000 *
<code>__IA64_REG_INDR_DBR</code>	9001
<code>__IA64_REG_INDR_IBR</code>	9002
<code>__IA64_REG_INDR_PKR</code>	9003
<code>__IA64_REG_INDR_PMC</code>	9004
<code>__IA64_REG_INDR_PMD</code>	9005
<code>__IA64_REG_INDR_RR</code>	9006
<code>__IA64_REG_INDR_RESERVED</code>	9007

\* `getIndReg` only

## Set Index Register Value ( `__setIndReg` )

The `__setIndReg` function copies a value into an indexed register. The function accesses a register (*index*) in a register file (*whichIndReg*) of 64-bit registers.

This function has the following format:

```
void __setIndReg (const int whichIndReg, __int64 index,
unsigned __int64 value);
```

**whichIndReg**

The register file.

**index**

The index in the register file of the hardware register to be set. See the `__getIndReg` function for the list of registers that can be accessed.

**value**

The value to which the register is set.

## Generate Break Instruction ( `__break` )

The `__break` function generates a break instruction with an immediate.

This function has the following format:

```
void __break (const int __break_arg);
```

**\_\_break\_arg**

An immediate value for the `__break` instruction to use.

## Serialize Data ( `__dsrlz` )

The `__dsrlz` function serializes data. Maps to the `srlz.d` instruction.

This function has the following format:

```
void __dsrlz (void);
```

## Flush Cache Instruction ( \_\_fc)

The \_\_fc function flushes a cache line associated with the address given by the argument. Maps to the fcr instruction.

This function has the following format:

```
void __fc (__int64 __address);
```

**\_\_address**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

## Flush Write Buffers ( \_\_fwb)

The \_\_fwb function flushes the write buffers. Maps to the fwb instruction.

This function has the following format:

```
void __fwb (void);
```

## Invalidate ALAT ( \_\_invalat)

The \_\_invalat function invalidates ALAT. Maps to the invala instruction.

This function has the following format:

```
void __invalat (void);
```



## Invalidate ALAT ( `__invala`)

The `__invala` function is the same as the `__invalat` function.

## Execute Serialize ( `__isrlz`)

The `__isrlz` function executes the serialize instruction. Maps to the `srlz.i` instruction.

This function has the following format:

```
void __isrlz (void);
```

## Insert Data Address Translation Cache ( `__itcd`)

The `__itcd` function inserts an entry into the data translation cache. Maps to the `itc.d` instruction.

This function has the following format:

```
void __itcd (__int64 pa);
```

**pa**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

## Insert Instruction Address Translation Cache ( `__itci`)

The `__itci` function inserts an entry into the instruction translation cache. Maps to the `itc.i` instruction.

This function has the following format:

```
void __itci (__int64 pa);
```

**pa**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

## Insert Data Translation Register ( `__itrd`)

The `__itrd` function maps to the `itr.d` instruction.

This function has the following format:

```
void __itrd (__int64 whichTransReg, __int64 pa);
```

**whichTransReg**

The data translation register to be used by the `itr.d` instruction.

**pa**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

## Insert Instruction Translation Register ( `__itri`)

The `__itri` function maps to the `itr.i` instruction.

This function has the following format:

```
void __itri (__int64 whichTransReg, __int64 pa);
```

**whichTransReg**

The data translation register to be used by the `itr.i` instruction.

**pa**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

## Purge Translation Cache Entry ( `__ptce` )

The `__ptce` function maps to the `ptc.e` instruction.

This function has the following format:

```
void __ptce (__int64 va);
```

**va**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

## Purge Global Translation Cache ( `__ptcg` )

The `__ptcg` function purges the global translation cache. Maps to the `ptc.g r, r` instruction.

This function has the following format:

```
void __ptcg (__int64 va, __int64 pagesz);
```

**va**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

**pagesz**

The address range of the purge.

## Purge Local Translation Cache ( `__ptcl` )

The `__ptcl` function purges the local translation cache. Maps to the `ptc.l r, r` instruction.

This function has the following format:

```
void __ptcl (__int64 va, __int64 pagesz);
```

**va**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

**pagesz**

The address range of the purge.

## Purge Global Translation Cache and ALAT ( `__ptcga` )

The `__ptcga` function purges the global translation cache and ALAT. Maps to the `ptc.ga r,r` instruction.

This function has the following format:

```
void __ptcga (__int64 va, __int64 pagesz);
```

**va**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

**pagesz**

The address range of the purge.

## Purge Data Translation Register ( `__ptrd` )

The `__ptrd` function purges the data translation register. Maps to the `ptr.d r, r` instruction.

This function has the following format:

```
void __ptrd (__int64 va, __int64 pagesz);
```

### **va**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

### **pagesz**

The address range of the purge.

## Purge Instruction Translation Register ( `__ptri` )

The `__ptri` function purges the instruction translation register. Maps to the `ptr.i r, r` instruction.

This function has the following format:

```
void __ptri (__int64 va, __int64 pagesz);
```

### **va**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

### **pagesz**

The address range of the purge.

## Reset System Mask ( `__rsm` )

The `__rsm` function resets the system mask bits of the PSR. Maps to the `rsm imm24` instruction.

This function has the following format:

```
void __rsm (int mask);
```

### **mask**

An integer value inserted into the instruction as a 24-bit immediate value.

## Reset User Mask ( `__rum` )

The `__rum` function resets the user mask.

This function has the following format:

```
void __rum (int mask);
```

### **mask**

An integer value inserted into the instruction as a 24-bit immediate value.

## Set System Mask ( `__ssm` )

The `__ssm` function sets the system mask.

This function has the following format:

```
void __ssm (int mask);
```

**mask**

An integer value inserted into the instruction as a 24-bit immediate value.

## Set User Mask ( `__sum` )

The `__sum` function sets the user mask bits of the PSR. Maps to the `sum imm24` instruction.

This function has the following format:

```
void __sum (int mask);
```

**mask**

An integer value inserted into the instruction as a 24-bit immediate value.

## Enable Memory Synchronization ( `__synci` )

The `__synci` function enables memory synchronization. Maps to the `sync.i` instruction.

This function has the following format:

```
void __synci (void);
```

## Translation Hashed Entry Address ( `__thash` )

The `__thash` function generates a translation hash entry address. Maps to the `thash r = r` instruction.

This function has the following format:

```
void __thash(__int64 __address);
```

**\_\_address**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

## Translation Hashed Entry Tag ( `__ttag` )

The `__ttag` function generates a translation hash entry tag. Maps to the `ttag r=r` instruction.

This function has the following format:

```
void __ttag(__int64 __address);
```

**\_\_address**

A 64-bit address, as opposed to a 32-bit or 64-bit pointer, that is loaded into a 64-bit general register used by the instruction to be generated.

## Atomic Compare and Exchange (`_InterlockedCompareExchange_acq`)

The `_InterlockedCompareExchange_acq` function atomically compares and exchanges the value specified by the first argument (a 64-bit pointer). This function maps to the `cmpxchg4.acq` instruction with appropriate setup.

This function has the following format:

```
unsigned __int64  _InterlockedCompareExchange_acq (volatile unsigned int
    *Destination,
                                     unsigned __int64 Newval, unsigned __int64 Comparand);
```

The value at *\*Destination* is compared with the value specified by *Comparand*. If they are equal, *Newval* is written to *\*Destination*, and *Oldval* is returned. The exchange will have taken place if the value returned is equal to the *Comparand*. The following algorithm is used:

```
ar.ccv = Comparand;
Oldval = *Destination;           //Atomic
if (ar.ccv == *Destination)     //Atomic
    *Destination = Newval;       //Atomic
return Oldval;
```

Those parts of the algorithm that are marked "Atomic" are performed atomically by the `cmpxchg4.acq` instruction. This instruction has acquire ordering semantics; that is, the memory read/write is made visible prior to all subsequent data memory accesses of the *Destination* by other processors.

### Destination

The value to be compared with *Comparand* and, if equal, replaced with the value of *Newval*.

### Newval

The new value to replace the value in *Destination*.

### Comparand

The value with which to compare *Destination*.

## Atomic Compare and Exchange (`_InterlockedCompareExchange64_acq`)

The `_InterlockedCompareExchange64_acq` function is the same as the `_InterlockedCompareExchange_acq` function, except that those parts of the algorithm that are marked "Atomic" are performed by the `cmpxchg8.acq` instruction.

This function has the following format:

```
unsigned __int64  _InterlockedCompareExchange64_acq (volatile unsigned
    __int64 *Destination,
                                     unsigned __int64 Newval, unsigned
    __int64 Comparand);
```

## Atomic Compare and Exchange (`_InterlockedCompareExchange_rel`)

This function is the same as the `_InterlockedCompareExchange_acq` function except that those parts of the algorithm that are marked "Atomic" are performed by the `cmpxchg4.rel` instruction with release ordering semantics; that is, the memory read/write is made visible after all previous memory accesses of the *Destination* by other processors.

This function has the following format:

```
unsigned __int64  _InterlockedCompareExchange_rel (volatile unsigned int
    *Destination,
                                     unsigned __int64 Newval, unsigned
    __int64 Comparand);
```

## Atomic Compare and Exchange (`_InterlockedCompareExchange64_rel`)

This function is the same as the `_InterlockedCompareExchange_rel` function, except that those parts of the algorithm that are marked "Atomic" are performed by the `cmpxchg8.rel` instruction.

This function has the following format:

```
unsigned __int64  _InterlockedCompareExchange64_rel (volatile unsigned
    __int64 *Destination,
                                     unsigned __int64 Newval, unsigned __int64 Comparand);
```

## Conditional Atomic Compare and Exchange Longword (`__CMP_SWAP_LONG`)

The `__CMP_SWAP_LONG` function performs a conditional atomic compare and exchange operation on a longword. The longword pointed to by *source* is read and compared with the longword *old\_value*. If they are equal, the longword *new\_value* is written into the longword pointed to by *source*. The read and write is performed atomically, with no intervening access to the same memory region.

The function returns 1 if the write occurs, and 0 otherwise.

This function has the following format:

```
int  __CMP_SWAP_LONG (volatile void *source, int old_value,
    int new_value);
```

### **source**

The longword value to be compared with *old\_value*.

### **old\_value**

The longword value *source* is compared with.

### **new\_value**

The longword value written into *source* if *source* and *old\_value* are equal.

## Conditional Atomic Compare and Exchange Quadword (`__CMP_SWAP_QUAD`)

The `__CMP_SWAP_QUAD` function performs a conditional atomic compare and exchange operation on a quadword. The quadword pointed to by *source* is read and compared with the quadword *old\_value*. If they are equal, the quadword *new\_value* is written into the quadword pointed to by *source*. The read and write is performed atomically, with no intervening access to the same memory region.

The function returns 1 if the write occurs, and 0 otherwise.

This function has the following format:

```
int __CMP_SWAP_QUAD (volatile void *source, int old_value,  
    int new_value);
```

### **source**

The quadword value to be compared with *old\_value*.

### **old\_value**

The quadword value *source* is compared with.

### **new\_value**

The quadword value written to *source* if *source* and *old\_value* are equal.

## Conditional Atomic Compare and Exchange Longword with Acquire Semantics (`__CMP_SWAP_LONG_ACQ`)

The `__CMP_SWAP_LONG_ACQ` function performs a conditional atomic compare and exchange operation with acquire semantics on a longword. The longword pointed to by *source* is read and compared with the longword *old\_value*. If they are equal, the longword *new\_value* is written into the longword pointed to by *source*. The read and write is performed atomically, with no intervening access to the same memory region.

Acquire memory ordering guarantees that the memory read/write is made visible *before* all subsequent data accesses to the same memory location by other processors.

The function returns 1 if the write occurs, and 0 otherwise.

This function has the following format:

```
int __CMP_SWAP_LONG_ACQ (volatile void *source, int old_value,  
    int new_value);
```

### **source**

The longword value to be compared with *old\_value*.

### **old\_value**

The longword value *source* is compared with.

### **new\_value**



The longword value written into *source* if *source* and *old\_value* are equal.

## Conditional Atomic Compare and Exchange Quadword with Acquire Semantics ( `__CMP_SWAP_QUAD_ACQ` )

The `__CMP_SWAP_QUAD_ACQ` function performs a conditional atomic compare and exchange operation with acquire semantics on a quadword. The quadword pointed to by *source* is read and compared with the quadword *old\_value*. If they are equal, the quadword *new\_value* is written into the quadword pointed to by *source*. The read and write is performed atomically, with no intervening access to the same memory region.

Acquire memory ordering guarantees that the memory read/write is made visible *before* all subsequent memory data accesses to the same memory location by other processors.

The function returns 1 if the write occurs, and 0 otherwise.

This function has the following format:

```
int __CMP_SWAP_QUAD_ACQ (volatile void *source, int old_value,
    int new_value);
```

### **source**

The quadword value to be compared with *old\_value*.

### **old\_value**

The quadword value *source* is compared with.

### **new\_value**

The quadword value written into *source* if *source* and *old\_value* are equal.

## Conditional Atomic Compare and Exchange Longword with Release Semantics ( `__CMP_SWAP_LONG_REL` )

The `__CMP_SWAP_LONG_REL` function performs a conditional atomic compare and exchange operation with release semantics on a longword. The longword pointed to by *source* is read and compared with the longword *old\_value*. If they are equal, the longword *new\_value* is written into the longword pointed to by *source*. The read and write is performed atomically, with no intervening access to the same memory region.

Release memory ordering guarantees that the memory read/write is made visible *after* all previous data memory accesses to the same memory location by other processors.

The function returns 1 if the write occurs, and 0 otherwise.

This function has the following format:

```
int __CMP_SWAP_LONG_REL (volatile void *source, int old_value,
    int new_value);
```

### **source**

The longword value to be compared with *old\_value*.

**old\_value**

The longword value *source* is compared with.

**new\_value**

The longword value written into *source* if *source* and *old\_value* are equal.

## Conditional Atomic Compare and Exchange Quadword with Release Semantics ( **\_\_CMP\_SWAP\_QUAD\_REL** )

The **\_\_CMP\_SWAP\_QUAD\_REL** function performs a conditional atomic compare and exchange operation with release semantics on a quadword. The quadword pointed to by *source* is read and compared with the quadword *old\_value*. If they are equal, the quadword *new\_value* is written into the quadword pointed to by *source*. The read and write is performed atomically, with no intervening access to the same memory region.

Release memory ordering guarantees that the memory read/write is made visible *after* all previous data memory accesses to the same memory location by other processors.

The function returns 1 if the write occurs, and 0 otherwise.

This function has the following format:

```
int  __CMP_SWAP_QUAD_REL (volatile void *source, int old_value,
    int new_value);
```

**source**

The quadword value to be compared with *old\_value*.

**old\_value**

The quadword value *source* is compared with.

**new\_value**

The quadword value written into *source* if *source* and *old\_value* are equal.

## Return Address ( **\_\_RETURN\_ADDRESS** )

The **\_\_RETURN\_ADDRESS** function produces the address to which the function containing the built-in call will return as a 64-bit integer (on Alpha systems, the value of R26 on entry to the function; on IA-64 systems, the value of B0 on entry to the function).

This built-in function cannot be used within a function specified to use nonstandard linkage.

This function has the following format:

```
__int64  __RETURN_ADDRESS (void);
```

## Implement Alpha **\_\_PAL\_GENTRAP** and **\_\_PAL\_BUGCHK** Builtins (**\_\_break2**)

The **\_\_break2** function is used to implement the Alpha **\_\_PAL\_GENTRAP** and **\_\_PAL\_BUGCHK** built-in functions on OpenVMS IA-64 systems.

The `__break2` function is equivalent to the `__break` function with the second parameter passed in general register 17:

```
R17 = <double_uscore>R17_value; <double_uscore>break
(<double_uscore>break_code);
```

This function has the following format:

```
void __break2 (__Integer_Constant __break_code, unsigned
__int64 __r17_value);
```

**`__breakcode`**

The particular software condition that has occurred.

**`__r17_value`**

The value of R17, a volatile general register reserved by the OpenVMS IA-64 calling standard for use by compiled code to communicate with specialized compiler support routines that require out-of-band information passing.

## Flush Register Stack ( `__flushrs` )

The `__flushrs` function flushes the register stack.

This function has the following format:

```
void __flushrs (void);
```

## Load Register Stack ( `__loadrs` )

The `__loadrs` function loads the register stack.

This function has the following format:

```
void __loadrs (void);
```

## Probe Read-Access Permission ( `__prober` )

The `__prober` function determines whether read access to the virtual address specified by `__address` bits {60:0} and the region register indexed by `__address` bits {63:61} is permitted at the privilege level given by `__mode` bits {1:0}. It returns 1 if the access is permitted, and 0 otherwise.

This function can probe only with equal or lower privilege levels. If the specified privilege level is higher (lower number), then the probe is performed with the current privilege level.

This function is the same as the Intel `__probe_r` function.

This function has the following format:

```
int __prober (__int64 __address, unsigned int __mode);
```

**`__address`**

Virtual address for which read-access permission is being checked.

**`__mode`**

Privilege level for which read-access permission is being checked.

## Probe Write-Access Permission ( `__probew` )

The `__probew` function determines whether write access to the virtual address specified by `__address` bits {60:0} and the region register indexed by `__address` bits {63:61}, is permitted at the privilege level given by `__mode` bits {1:0}. It returns 1 if the access is permitted, and 0 otherwise.

This function can probe only with equal or lower privilege levels. If the specified privilege level is higher (lower number), then the probe is performed with the current privilege level.

This function is the same as the Intel `__probe_w` function.

This function has the following format:

```
int __probew (__int64 __address, unsigned int __mode);
```

**`__address`**

Virtual address for which write-access permission is being checked.

**`__mode`**

Privilege level for which write-access permission is being checked.

## Translation Access Key ( `__tak` )

The `__tak` function returns the translation access key.

This function has the following format:

```
unsigned int __tak (__int64 __address);
```

**`__address`**

Virtual address for translation key is being returned.

## Translate to Physical Address ( `__tpa` )

The `__tpa` function translates a virtual address to a physical address.

This function has the following format:

```
__int64 __tpa (__int64 __address);
```

**`__address`**

Virtual address to be translated.

# B.3. Built-In Functions for x86-64 Systems (x86-64 only)

The VSI C++ built-in functions available on OpenVMS IA-64 systems are not fully supported on x86-64 systems. The `<builtins.h>` header file contains comments noting which built-in functions are available or not on x86-64 systems. Currently the following sets of built-in functions are supported:

```
__ATOMIC_ADD_LONG
__ATOMIC_ADD_LONG_RETRY
__ATOMIC_AND_LONG
__ATOMIC_AND_LONG_RETRY
__ATOMIC_OR_LONG
__ATOMIC_OR_LONG_RETRY
__ATOMIC_INCREMENT_LONG
__ATOMIC_INCREMENT_LONG_RETRY
__ATOMIC_DECREMENT_LONG
__ATOMIC_DECREMENT_LONG_RETRY
__ATOMIC_EXCH_LONG
__ATOMIC_EXCH_LONG_RETRY
__ATOMIC_ADD_QUAD
__ATOMIC_ADD_QUAD_RETRY
__ATOMIC_AND_QUAD
__ATOMIC_AND_QUAD_RETRY
__ATOMIC_OR_QUAD
__ATOMIC_OR_QUAD_RETRY
__ATOMIC_INCREMENT_QUAD
__ATOMIC_INCREMENT_QUAD_RETRY
__ATOMIC_DECREMENT_QUAD
__ATOMIC_DECREMENT_QUAD_RETRY
__ATOMIC_EXCH_QUAD
__ATOMIC_EXCH_QUAD_RETRY
```

---

## Note

RETRY variants are converted to their counterparts without `_RETRY` and always succeed.

---

The queue manipulation builtins are supported through macros or wrapper functions defined in the `<builtins.h>` header file. Builtin calls are transformed to calls to OpenVMS system services `SYS$<name>`, where `<name>` is the name of the builtin with the leading underscores removed.

```
__PAL_INSQHIL
__PAL_INSQTIL
__PAL_INSQUEL
__PAL_INSQUEL_D
__PAL_INSQHILR
__PAL_INSQTILR
__PAL_REMQHIL
__PAL_REMQTIL
__PAL_REMQUEL
__PAL_REMQUEL_D
__PAL_REMQHILR
__PAL_REMQTILR
__PAL_INSQHIQ
__PAL_INSQTIQ
__PAL_INSQUEQ
__PAL_INSQUEQ_D
__PAL_INSQHIQR
__PAL_INSQTIQR
__PAL_REMQHIQ
__PAL_REMQTIQ
__PAL_REMQUEQ
__PAL_REMQUEQ_D
__PAL_REMQHIQR
__PAL_REMQTIQR
```

The built-in descriptions correspond to descriptions for IA-64 (see *Section B.2, "Built-In Functions for IA-64 Systems (IA-64 only)"*).

# Appendix C. Class Library Restrictions (Alpha and IA-64 only)

This appendix describes known problems and restrictions for the Class Library. Please note that **String Package**, which is part of the Class Library, is entirely different from the String class that is part of the newly-implemented C++ Standard Library and known as the **String Library**. Do not confuse these two contrasting implementations.

## C.1. Class Library Restrictions

The following are restrictions in the C++ Class Library:

- No Class Library support for 128-bit long doubles

The Class Library does not include support for 128-bit long doubles.

- Conflict with redefinition of `clear()`

If your program includes both `< curses.h>` and `<iostream.hxx>`, VSI C++ might fail to compile your program because `clear()` is defined by both header files. In `< curses.h>`, `clear()` is defined as a macro whereas in `<iostream.hxx>` `clear()` is defined as a member function.

Workarounds:

If your program does not use either `clear()` or uses the `clear()`, include the `<iostream.hxx>` header first, followed by `< curses.h>`.

If your program uses the `ios::clear()` function, undefine the `clear()` macro directly after the `#include < curses.h>` statement.

- On OpenVMS Alpha systems, class library IOStreams do not support denormalized IEEE numbers. The workaround is to use C Run-Time Library functions like `printf` and `scanf` instead.





# Appendix D. Compiler Compatibility (Alpha and IA-64 only)

This appendix describes VSI C++ compatibility with other C++ compilers, and documents compatibility concerns between the Version 5.*n* and Version 6.*n* compilers.

For porting and compatibility between Alpha and IA-64 systems, see *Chapter 4, "Porting Applications to IA-64 Systems"*.

For porting and compatibility between Alpha and IA-64 systems, see *Chapter 5, "Porting Applications from IA-64 to x86-64 Systems"*.

VSI C++ implements the C++ International Standard, with some differences, as described in the C++ release notes.

This language differs significantly from *The Annotated C++ Reference Manual*, implemented by the Version 5.*n* compilers. When switching from a Version 5.*n* compiler, you might need to modify your source files, especially if you use the default language mode. In addition, language changes can affect the run-time behavior of your programs. If you want to compile existing source code with minimal source changes, compile using the `/STANDARD=ARM` qualifier option. See *Chapter 8, "The C++ Standard Library"* for information on and changes to the Standard Library.

This chapter describes ways to avoid having the compiler reject program code that previously worked with other C++ implementations that adhere less strictly to the C++ language definition. References to applicable portions of *The Annotated C++ Reference Manual* indicate where you can find additional help.

## D.1. Compatibility with Other C++ Compilers

In default mode (`/STANDARD=RELAXED`), the compiler implements most features of the C++ International Standard, including:

- Run-time type identification (RTTI), with `dynamic_cast` and the `typeid` operator (see *Section 2.4, "Run-time Type Identification"*)
- New-style casts (`static_cast`, `reinterpret_cast`, and `const_cast`)
- Array new and delete

For compatibility with previous versions, the compiler provides the following language mode options:

### **`/STANDARD=RELAXED`**

Specify this option if you want an ANSI C++ compiler that supports some commonly used extensions and is somewhat less strict than the standard. This is the default compiler mode. Please note that `/STANDARD=ANSI` is accepted as a synonym for `/STANDARD=RELAXED` to be compatible with previous compiler versions.

If you want to use RELAXED mode but find that the compiler generates too many diagnostics in that mode, you can use the `/QUIET` option with the `/STANDARD=RELAXED` option. The `/QUIET` option relaxes error checking and suppresses or reduces the severity of many diagnostics. It also

suppresses many warnings that are generated in RELAXED mode but were not issued by Version 5.*n* compilers. For information on message control options, see *Section 2.5, "Message Control and Information Options"*.

#### **/STANDARD=ARM**

Specify this option if you want to compile programs developed using Version 5.*n* and want to minimize source changes.

VSI C++ Version 6.*n* and higher also provides support for other C++ dialects and language modes. You can specify the following options:

#### **/STANDARD=MS**

Specify this option if you want the compiler to accept additional Microsoft Visual C++ extensions.

With /STANDARD=MS you may also want to specify /QUIET to reduce the number of diagnostic messages generated.

#### **/STANDARD=STRICT\_ANSI**

Enforce the ANSI standard strictly but permit some ANSI violations that should be errors to be warnings. To force ANSI violations to be issued with Error instead of Warning severity, use /WARNINGS=ANSI\_ERRORS in addition to /STANDARD=STRICT\_ANSI.

#### **/STANDARD=LATEST**

Use the latest C++ standard dialect. /STANDARD=LATEST is currently equivalent to /STANDARD=STRICT\_ANSI, but is subject to change when newer versions of the C++ standard are released.

## **D.2. Compatibility with Version 5.6 and Earlier**

This section provides details about differences between the Version 6.*n* and later compilers, and the Version 5.6 and earlier compilers:

- Language differences
- Implementation differences
- Library differences

### **D.2.1. Language Differences**

Users should be aware of the following language differences between Version 6.*n* and higher (denoted simply as Version 6.*n* in the following list), and previous versions of the compiler.

- The most important language differences result from the current implementation of the C++ International Standard in the Version 6.*n* compilers. If you want to compile existing source code with minimal source changes, compile using the /STANDARD=ARM option.
- Because the Version 6.*n* compilers perform more error checking than previous versions, they generate significantly more diagnostic messages. However, you can use the /QUIET option to relax error checking and reduce the severity of many diagnostics. *Message Control and Information Options*.
- The following keywords, introduced with the C++ International Standard, are always reserved keywords in all compiler modes:

`bool`, `const_cast`, `explicit`, `export`, `false`, `mutable`, `dynamic_cast`,  
`reinterpret_cast`, `static_cast`, `true`, `typeid`, `typename`, `wchar_t`

Alternative representation keywords are as follows:

`and`, `and_eq`, `bitand`, `bitor`, `compl`, `not`, `not_eq`, `or`, `or_eq`, `xor`, `xor_eq`

- Taking the address of a bit field is not allowed in the current version.
- Creation of temporaries and their lifetimes vary among compiler modes.
- Macro expansion in pragmas can give different results in the current and previous versions.
- The following are distinct types in the Version 6.*n* compilers; they were the same type in previous versions:

```
typedef void (*PF)();           // Pointer to an extern "C++" function
extern "C" typedef void (*PCF)(); // Pointer to an extern "C" function
void f(PF);
void f(PCF);
```

- Version 6.*n* does not allow converting a pointer to member from a derived class to a virtual base class.
- Calling a nonstatic member function through a null pointer is undefined behavior. Certain cases that used to run without errors in previous versions no longer run in the current version. For example:

```
#include <iostream.h>
struct A {
    int a;
};
struct D : public virtual A
{
    A* toA(){ return (A*) this; }
};
main ()
{
    D* d = NULL;
    A* ad = d->toA(); // will ACCVIO
    if (ad==NULL) cout << "ok";
}
```

- In Version 6.*n* compilers, `bool` is a built-in type. In previous versions, it is user-defined, typically as `int` in system header files. Mangling differs in this respect only for functions that have arguments of type `bool`.

In Version 6.*n* compilers, the size of `bool` is 1. In previous versions, `bool` is user defined, typically as `int` with a size of 4.

In Version 6.*n* compilers, the size of a boolean expression ( `sizeof(a && b)` ) is 1. In previous versions, the size is 4, independent of the size of `bool`.

- Version 6.*n* compilers do not cause pragmas to become effective within function bodies when scanning template definitions.
- Version 6.*n* compilers do not allow the “virtual” storage class modifier to be used with member function definitions outside a class.

- Version 6.*n* compilers do not allow declaration of pointers to members of type `void`. For example, the following is not allowed:

```
typedef void Z::* any_ptom;
```

## D.2.2. Implementation Differences

Users should be aware of the following implementation differences between Version 6.*n* compilers, and previous versions of the compiler:

- The automatic template instantiation model is different for Version 6.*n*, and previous compiler versions. See *Section D.2.3, "Using Templates"* for details.

It is different yet again for IA-64 systems. See *Chapter 6, "Using Templates"* for details.

- Version 6.*n* and higher drops qualifiers on parameters when determining the function type, as dictated by the C++ International Standard. For instance, in the following example, the function declarations are the same function.

```
f(const int p1);  
f(int p1);
```

For compatibility with previous versions, if qualifiers are included in function declarations, they are also included in the mangled name. (Note: this is not true for model ANSI or for IA-64 systems.)

- Version 6.*n* differs from previous versions in interpreting undefined behavior, as when incrementing takes effect in this example:

```
f(i++, i++);
```

- Version 6.*n* cannot handle a `#pragma define_template` that spans multiple lines without the backslash (`\`) delimiter. Version 5.6 can handle this without problems.
- Version 6.*n* displays `#line number` in `/PREPROCESS_ONLY` output. The previous version displays `#number`.
- After encountering an illegal multibyte character sequence, Version 6.*n* issues a warning diagnostic and continues processing. The previous version issues an error and stops processing.
- Version 6.*n* does not support VAX C module include syntax (for example, `#include acms $submitter` without `<>` or `" "` delimiters). The compiler searches text libraries for modules included using the normal include syntax (specifying the `" "` or `<>` delimiters) and correctly (according to the C++ standard) rejects `#include` directives that do not follow this syntax.

## D.2.3. Using Templates

The template instantiation model was completely redesigned for C++ Version 6.0. The changes include:

- Automatic template instantiation now occurs at compile time. Necessary templates are instantiated automatically by the compilation of the source file that needs them and has access to the template definitions.
- During automatic template instantiation, instantiations are written into the repository as object files. Compilation of instantiations is no longer done at link time.
- For automatic instantiation, the compiler no longer requires that template declarations and definitions appear in header files.

- `Template.map` files are no longer supported as a way to match template declarations and definitions.
- Several new manual template instantiation pragmas have been added.

The automatic template instantiation model new with Version 6.0 is not directly compatible with previous template instantiation mechanisms. When linking applications using Version 6.0 and later, instantiations might not be resolved from existing Version 5.*n* repositories. Where possible, it is safest to start fresh with an empty repository and create the required instantiations by compiling all source files. If this is not possible, there are some strategies that can be used to link mixed generation instantiations.

If you used both Version 6.*n* and Version 5.*n* to build applications, VSI strongly recommends that you use different repositories to contain automatic template instantiations for Version 6.*n* and Version 5.*n* compilations. The default repository name is the same for Version 6.*n* as for prior versions. Thus, if you use Version 6.*n* with older pre-6.*n* versions, you should do compilations in a different directory for each compiler or explicitly specify a different repository for each using the `/REPOSITORY` qualifier.

### D.2.3.1. Linking with Version 5.*n* Instantiations

When linking applications using Version 6.*n* against instantiations created with Version 5.*n*, it is necessary to complete the Version 5.*n* instantiation process, to create instantiation object files. If `old_repository` is a Version 5.*n* repository then you would create the Version 5.*n* instantiation object files by using the Version 5.*n* `cxxlink`:

```
CXXLINK/NOEXE /REPOSITORY=[.old_repository]
    <Version 5.n object files>
```

<Version 5.*n* object files> are the object files that were created using the Version 5.*n* compiler; `old_repository` now contains the instantiation object files. Create a library of these object files as follows:

```
LIBRARY/CREATE/OBJECT lib_old_repository/LOG
LIBRARY/INSERT/OBJECT lib_old_repository/LOG
    [old_repository]*.obj
```

When linking using Version 6.*n*, specify `lib_old_repository.olb` after all of the Version 5.*n* object files that are being linked.

### D.2.3.2. Linking Version 5.*n* Applications Against Version 6.*n* Repositories

In a similar way, you can create a library of Version 6.*n* instantiation object files to link into a Version 5.*n* application being linked using C++ Version 5.*n*. If `new_repository` is the Version 6.*n* repository, then a library of the instantiations would be created by:

```
LIBRARY/CREATE/OBJECT lib_new_repository/LOG
LIBRARY/INSERT/OBJECT lib_new_repository/LOG [new_repository]*.obj
```

When linking using Version 5.*n*, specify `lib_new_repository.olb` after all of the Version 6.*n* object files that are being linked.

## D.2.4. Library Differences

Aspects of memory allocation and deallocation have changed from the V5.*n* and earlier compilers to the Version 6.*n* compilers. See the description of `/[NO]STDNEW` and `/[NO]GLOBAL_ARRAY_NEW` in *The C++ Standard Library*.

## D.3. Using Classes

This section discusses porting issues pertaining to C++ classes.

### D.3.1. Friend Declarations

When making `friend` declarations, use the elaborated form of type specifier. The following code fragment implements the legal and comments out the illegal `friend` declaration:

```
class Y;
class Z;
class X;
    //friend Y;    ** not legal
    friend class Z; // legal
};
```

### D.3.2. Member Access

Unlike some older C++ implementations, VSI C++ strictly enforces accessibility rules for `public`, `protected`, and `private` members of a base class. For more information, see *The Annotated C++ Reference Manual*.

### D.3.3. Base Class Initializers

Unlike some older C++ implementations, VSI C++ requires you to use the base class name in the initializer for a derived class. The following code fragment implements a legal initializer and comments out an illegal initializer:

```
class Base {
    // ...
public:
    Base (int);
};
class Derived : public Base {
    // ...
public:
    // Derived(int i) : (i)  { /* ... */ }    ** not legal
    Derived(int i) : Base(i) { /* ... */ } // ** legal, supplies class name
};
```

For more information, see *The Annotated C++ Reference Manual*.

## D.4. Undefined Global Symbols for Static Data Members

When a static data member is declared, the compiler issues a reference to the external identifier in the object code, which must be resolved by a definition. The compiler does not support the declaration anachronism shown in *The Annotated C++ Reference Manual*.

For example, consider the following code fragment:

```
class C {
    static int i;
```

```
};  
//missing definition  
//int C::i = 5;  
int main ()  
{  
    int x;  
    x=C::i;  
    return 0;  
}
```

The compiler does not issue any messages during compilation; however, when you attempt to link a program containing this code, the linker issues an unresolved symbol error message for the variable `C::i`.

## D.5. Functions and Function Declaration Considerations

VSI C++ requires the use of function definitions as described in *The Annotated C++ Reference Manual*. For examples of outdated syntax not allowed in VSI C++, see *The Annotated C++ Reference Manual*.

Because all linkage specifications for a name must agree, function prototypes are not permitted if the function is later declared as an inline function. The following code is an example of such a conflicting function declaration:

```
int f();  
inline int f() { return 1; }
```

In this example, `f` is declared with both internal and external linkage, which causes a compiler error.

## D.6. Using Pointers

This section demonstrates how to use pointers effectively in VSI C++.

### D.6.1. Pointer Conversions

In VSI C++, you cannot implicitly convert a `const` pointer to a nonconstant pointer. For example, `char *` and `const char *` are not equivalent; explicitly performing such a cast can lead to unexpected results.

For more information, see *The Annotated C++ Reference Manual*.

### D.6.2. Bound Pointers

Binding a pointer to a member function with a particular object as an argument to the function is not allowed in VSI C++. For more information on the illegality of casting bound pointers, see *The Annotated C++ Reference Manual*.

### D.6.3. Constants in Function Returns

Because the return value cannot be an lvalue, the `const` keyword in a function return has no effect on the semantics of the return. However, using the `const` keyword in a function return does affect the type signature. For example:

```
static int f1( int a, int b) {;}
const int (* const (f2[])) (int a, int b) = {f1};
```

In this example, the referenced type of the pointer value `f1` in the initializer for `f2[ ]` is *function* (signed int, signed int), which returns signed int. This is incompatible with *function* (signed int, signed int), which returns const signed int.

You can omit the `const` of `int` because it affects only the constant return signature.

## D.6.4. Pointers to Constants

The following example shows a type mismatch between a pointer to a `char` and a pointer to a `const char` that some other compilers might not find:

```
void foo (const char* argv[]) {}
int main()
{
    static char* args[2] = {"foo", "bar"};
    /* In this statement, the referenced type of the pointer value
       "args" is "pointer to char" which is not compatible with
       "pointer to const char" */
    foo (args);
    return 0;
}
```

You can correct this example by changing `static char` to `static const char`. Use an explicit type cast to get an argument match only if no other option is available; such a cast may break on some C++ implementations.

## D.7. Using typedefs

Using a synonym after a `class`, `struct`, or `union` prefix is illegal. Using a synonym in the names for constructors and destructors within the class declaration itself is also illegal.

In the following example, the illegal `typedef` specifier is commented out:

```
typedef struct { /* ... */ } foo;
// typedef struct foo foobar;          ** not legal
```

For more information, see *The Annotated C++ Reference Manual*.

## D.8. Initializing References

VSI C++ warns against initializing nonconstant references to refer to temporary objects. The following example demonstrates the problems that can result:



```
static void f()
{
    int i = 5;
    i++;           // OK
    int &ri = 23;
    ri++;          // In the initializer for ri, the initialization of a
                  // non-const reference requires a temporary for "23".
}
```

The issue of reference initialization arises most often in assignment operators and in copy constructors. Wherever possible, declare all reference arguments as `const`.

For more information, see *The Annotated C++ Reference Manual*.

## D.9. Using the switch and goto Statements

Branching around a declaration with an explicit or implicit initializer is not legal, unless the declaration is in an inner block that is completely bypassed. To satisfy this constraint, enclose the declaration in a block. For example:

```
int i;
switch (i) {
case 1:
    int l = 0;           //not initialized at this case label
    myint m = 0;         //not initialized at this case label
    {
        int j = 0;       // legal within the braces
        myint m = 0;     // legal within the braces
    }
case 2:
    break;
// ...
}
```

For more information on using the `switch` statement, see *The Annotated C++ Reference Manual*.

## D.10. Using Volatile Objects

You must supply the meaning of copy constructing and assigning from volatile objects, because the compiler generates no copy constructors or assignment operators that copy or assign from volatile objects. The following example contains examples of such errors, as noted in the comments:

```
class A {
public:
    A() { }
    // A(volatile A&) { }
    // operator=(volatile A&) { return 0; }
};
void foo()
{
    volatile A va;
    A a;
    A cca(va); // error - cannot copy construct from volatile object
    a = va;    // error - cannot assign from volatile object
    return;
}
```

For more information, see *The Annotated C++ Reference Manual*.

## D.11. Preprocessing

VSI C++ allows identifiers, but not expressions, on the `#ifdef` preprocessor directive. For example:

```
// this is not legal
// #ifdef KERNEL && !defined(__POSIX_SOURCE)
```

The following is the legal alternative:

```
// use this instead
#if defined(KERNEL) && !defined(__POSIX_SOURCE)
```

For more information, see *The Annotated C++ Reference Manual*.

## D.12. Managing Memory

The proper way to manage memory for a class is to overload the `new` and `delete` operators. This is in contrast to some older C++ implementations, which let you manage memory through assignment to the `this` pointer.

For more information, see *The Annotated C++ Reference Manual*.

Program developers must take care that any user-defined `new` operators always return pointers to quadword-aligned memory.

## D.13. Size-of-Array Argument to delete Operator

If a size-of-array argument accompanies a `delete` operator, VSI C++ ignores the argument and issues a warning. The following example includes an anachronistic use of the `delete` operator:

```
int main()
{
    int *a = new int [20];
    int *b = new int [20];
    delete[20] a;      //old-style; argument ignored, warning issued
    delete[] b;
    return 0;
}
```

## D.14. Flushing the Output Buffer

Do not depend on the newline character (`\n`) to flush your terminal output buffer. A previous stream implementation might have done so, but this behavior is not in conformance with Version 2.0 of the AT&T `iostream` library. If you want to flush the output buffer, use the `endl` manipulator or the `flush` member function.

## D.15. Linking

When linking applications, use `CXXLINK` instead of `LINK`. See *Section 1.3, "Linking a Program (Alpha only)" (Alpha only)* and *Section 1.4, "Linking a Program (IA-64 only)" (IA-64 only)*.

## D.16. Incrementing Enumerations

Some other C++ implementations let you perform integer arithmetic, including ++, on enumerated types; VSI C++ does not allow this.

## D.17. Guidelines for Writing Clean 64-Bit Code

Paying careful attention to data types can ensure that your code works on both 32-bit and 64-bit systems. Use the following guidelines to write clean 64-bit code:

- Variables that should be 32 bits in size on both 32-bit systems and 64-bit OpenVMS systems should be declared as `int` (not `long`).
- If you want 32-bit variables on a 32-bit system and an OpenVMS system, declare them as `int`.
- A 64-bit number on OpenVMS must be declared as `__int64` or `long long`.
- Remember that `register` variables and unsigned variables default to `int` (32 bits).
- Constants are 32-bit quantities by default. Performing shift operations or bit operations on constants will give 32-bit results. You must add `L` to the constant to get a 64-bit result. For example:

```
long foo, bar;  
foo = 1L << bar;
```

- Assigning to a `char` is not atomic on OpenVMS systems. You will get a load of 32 or 64 bits, followed by byte operations to extract, mask, and shift the byte, followed by a store of 32 or 64 bits.
- Bit-fields declared as `int` on OpenVMS systems generate load/store 32 bits. Bit-fields declared as `long` on OpenVMS systems generate load/store 64 bits.
- If you do not explicitly declare the formal parameters to functions, their sizes may not match the caller sizes. The default is `int`, which truncates 64-bit addresses.
- The `%d` and `%x` format specifiers print 32 bits of data. Use `%Ld` or `%Lx` with `printf` to print 64 bits of data. You can use `%p` on both 32- and 64-bit systems to print the value of pointers.

