Exemplar C and Fortran 77 Programmer's Guide

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How to use this guide

Purpose and audience

This guide describes how to use the Exemplar C and Fortran 77 compilers. It describes the differences between the Exemplar compilers running on SPP-UX and the standard Hewlett-Packard (HP) compilers on which they are based. All Exemplar-specific features are described in detail. This guide also describes the differences between the Exemplar compilers and the SPP1000-Series compilers (/usr/convex/bin/cc and /usr/convex/bin/fc).

The target audience for this book is the experienced C or Fortran 77 programmer who has a basic familiarity with SPP-UX, HP-UX, or Unix and is using V1.0 (or higher) of one of the Exemplar compilers to produce applications for SPP-UX V5.0 or higher running on an SPP1200, SPP1600, S-Class server, or X-Class server.

Note

This book is a preliminary version of the book that will be available with the official release of the compilers and does not reflect the functionality of the compilers at the official release.

Organization

This guide is organized as follows:

- Chapter 1 introduces the Exemplar compilers and provides some standard HP compiler information and examples.
- Chapter 2 describes the Exemplar extensions to the standard HP compilers, including options, directives and pragmas, Fortran 77 language extensions, and predefined preprocessor symbols.
- Chapter 3 describes differences between the Exemplar compilers and the SPP1000-Series compilers in terms of available options, directives and pragmas, and Fortran 77 language extensions.
- Chapter 4 provides a quick overview of how the Exemplar assembler and linker utilities differ from the HP-UX versions on which they are based. This chapter also describes the SOM and ESOM files and the linker support for the CXdb debugger and the CXpa profiler.
- Chapter 5 gives an overview of the CXdb debugger and the CXpa profiler.
- Chapter 6 explores system utilities that can be helpful in programming an SPP-UX system.
- Appendix A describes common environment variables that the Exemplar compilers accept.

Notational conventions

This section discusses notational conventions used in this book.

`Bold monospace`

In command examples, text shown in **`bold monospace`** identifies user input that must be typed exactly as shown.

`Monospace`

In paragraph text, `monospace` identifies command names, system calls, and directive/pragma names.

In command examples, `monospace` identifies command output, including error messages.

In command syntax diagrams, text shown in `monospace` must be typed exactly as shown.

Italic

In paragraph text, *italic* identifies new and important terms and titles of documents.

In command syntax diagrams, *italic* identifies variables that must be supplied by the user.

{ }

In command syntax diagrams, text surrounded by curly brackets indicates a choice. The choices available are shown inside the curly brackets and separated by the pipe (|) sign.

The following command example indicates that you can enter either a or b:

```
command {a | b}
```

[ ]

In command syntax diagrams and directive/pragma specifications, square brackets indicate optional data.

The following command example indicates that the variable *output_file* is optional:

`command` *input_file* [*output_file*]

...

In command syntax, horizontal ellipses show repetition of the preceding item(s).

The following command example indicates you can optionally specify more than one *input_file* on the command line:

`command` *input_file* [*input_file ...*]

Exemplar compilers

The Hewlett-Packard Exemplar C and Fortran 77 compilers are based on 10.2x releases of the corresponding Hewlett-Packard compilers. The Exemplar compilers support the creation, debugging, and profiling of thread-parallel applications running on SPP-UX V5.0 or higher.

SPP1000-Series compilers

The phrase *SPP1000-Series compilers* refers to the /usr/convex/bin/cc and /usr/convex/bin/fc compilers. Hewlett-Packard now ships the Exemplar compilers in place of the SPP1000-Series compilers.

Standard HP compilers

The phrase *standard HP compilers* refers to the `c89` and `f77` compilers developed by Hewlett-Packard Company.

Notes

This document presents notes in the following format:

Note

A Note highlights supplemental information.

Associated documents

Hewlett-Packard Company provides the following documents to help you use the `c89` and `f77` compilers and associated tools:

- *Programming on HP-UX* (B2355-90652)—This book describes how to develop software on HP-UX using the HP compilers, assemblers, linker, libraries, and object files.
- *HP C/HP-UX Reference Manual* (92453-90024)—This manual presents reference information on the C programming language—as implemented by Hewlett-Packard.
- *HP C/HP-UX Programmer's Guide* (92434-90002)—This guide contains detailed discussions of selected C topics.
- *FORTRAN/9000 Programmer's Reference* (B3906-90002)—This book is a language reference.
- *FORTRAN/9000 Programmer's Guide* (B3906-90001)—This manual is a task reference. It describes features and requirements in terms of the tasks a programmer might perform. These tasks include how to compile, link, run, debug, and optimize programs.
- *CXdb Reference* (DSW-611)—This book describes the CXdb visual debugger.
- *CXdb Quick Reference* (DSW-612)—This book covers the more frequently used features of CXdb.
- *CXpa Reference* (DSW-605)—This book describes the CXpa performance analyzer.
- *Exemplar Programming Guide* (DSW-067)—This book describes efficient shared-memory programming techniques using the SPP1000-Series compilers (/usr/convex/bin/cc, /usr/convex/bin/fc).
- *HP MPI User's Guide* (DSW-493)—This book discusses message-passing programming using the Message-Passing Interface library.
- *HP PVM User's Guide* (DSW-501)—This book discusses message-passing programming using the Parallel Virtual Machine library.
- *HP Fortran 90 Programmer's Reference* (720-008730-000)—This book is a complete Fortran 90 language reference. It also covers compiler options, compiler directives, and library information.
- *HP Fortran 90 1.0 Programmer's Notes* (DSW-???—not currently available)—This book provides extensive usage information, including how to compile and link, suggestions and tools for migrating to HP Fortran 90, and how to call C and HP-UX routines from HP Fortran 90.

- *Assembly Language Reference Manual* (92432-90001)—This manual describes the use of the Precision Architecture RISC (PA-RISC) Assembler.
- *SPP-UX System Administrator's Guide* (DSW-853)—This manual describes fundamental concepts and tasks associated with setting up and maintaining an S-Class or X-Class system.
- The following man pages:
  - as(1)
  - c89(1)
  - cxdb(1)
  - cxoi(1)
  - cxpa(1)
  - f77(1)
  - file(1)
  - largefiles(1m)
  - ld(1)
  - make(1)
  - mpa(1)
  - nm(1)
  - pot(1)
  - scm(1) man page
  - size(1) man page
  - sod(1) man page
  - sysinfo(1) man page
  - syspic(1) man page
  - top(1) man page

Ordering documents

To order the current edition of this or any other document listed in this book, send requests to:

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P.O. Box 833851
Richardson TX 75083-3851 USA

Please include the order number (DSW or DHW number) or the exact title and edition of the document.

Technical assistance

If you have questions that are not answered in this book or in the documents listed in the section "Associated documents" on page xvi, contact the CXD Technical Assistance Center (TAC) at the following locations:

Within the continental U.S., call 1-800-952-0379.

From Canada, call 1-800-345-2384.

All other locations, contact the local Convex Division office.

You can also use the `contact` utility, if you would like to report any problems you may have with the Exemplar compilers or the documentation. For more information refer to the contact(1) man page.

Introduction 1

This chapter introduces the Hewlett-Packard Exemplar C compiler (`c89`) and Fortran 77 compiler (`f77`). These compilers are based on the 10.2x releases of the standard Hewlett-Packard `c89` and `f77` compilers and are designed for creating applications for SPP-UX V5.0 or higher.

The programming model

The Exemplar compilers implement a subset of the Exemplar programming model, which provides advanced parallelism. This model supports the following programming paradigms:

- Shared-memory
- Message-passing
- Shared-memory/message-passing

In the shared-memory paradigm, the compilers perform optimizations and—if requested—parallelization. Directives and pragmas allow the user to further increase optimization opportunities.

Under the message-passing paradigm, functions explicitly spawn parallel processes, share data among processes, and coordinate their activities.

The shared-memory/message-passing paradigm allows the user to combine the two paradigms, taking advantage of their respective strengths.

This book focuses on the compiler support for the shared-memory paradigm. See the *Exemplar Programming Guide* for information on programming efficiently using the shared-memory paradigm.

See the *HP MPI User's Guide* and the *HP PVM User's Guide* for information on using message passing.

Standard HP compiler information

This section discusses some of the standard HP compiler options that are referenced later in this book. However, this book is intended as a supplement to the standard HP compiler documentation. See the c89(1) and f77(1) man pages, for:

- Command-line options that are used most often
- Optimization options
- Input files information
- Diagnostics information
- Environment variables

See the section "Associated documents" on page xvi for a list of additional documentation.

Note

The exact optimizations performed by the SPP1000-Series compilers (/usr/convex/bin/fc, /usr/convex/bin/cc) are not available in the Exemplar compilers. The Exemplar compilers perform the optimizations supported by the standard HP compilers.

+O0 (default)

Optimization level +O0 is the default. Your code compiles fastest at this level, but with little optimization. Code development and debugging should be done at this level.

At optimization level +O0, the optimizations in Table 1 are performed.

Table 1 Optimizations performed at +O0

Optimization	Description
Constant folding	Constant folding is the replacement of an operation on constant operands with result of the operation
Partial evaluation of test conditions	Where possible, determines the truth value of a logical expression without evaluating all the operands (also known as short circuiting)

+O1

The transformations performed at +O1 are local to small subsections of code and, therefore, are performed quickly and with little runtime storage required by the compiler. Use +O1 when some optimization is desired, but when compile-time performance is more important than runtime performance.

At optimization level +O1, the optimizations listed in Table 2 are performed.

Table 2 Optimizations performed at +O1

Optimization	Description
The +O0 optimizations	
Branch optimizations	Changes branch instructions into more efficient sequences
Dead code elimination	Removes code that is unreachable or is otherwise never executed
Instruction scheduling	Schedules instructions to take advantage of pipelining
More efficient use of registers	
Peephole optimizations	Replaces assembly language instruction sequences with faster sequences and removes redundant register loads and stores

+O2, -O

You can use either -O or +O2 to enable the +O2 optimizations.

Transformations at +O2 are performed over the scope of each procedure. If you use this optimization level, the compiler uses more memory than at +O1 and takes longer to process your program. Optimizing procedures of more than 1,000 lines at this level takes considerably longer than at +O1.

At optimization level +O2, the optimizations in Table 3 are performed:

Table 3 Optimizations performed at +O2

Optimization	Description
The +O0 and +O1 optimizations	
Coloring register allocation	Determines when and how long commonly used variables and expressions occupy a register
Induction variable recognition	Removes linear functions of a loop counter and replaces them with the loop counter
Strength reduction	Replaces some multiplication instructions with addition instructions
Common subexpression elimination	Replaces subsequent instances of an expression with its result
Advanced constant folding and propagation (Simple constant folding is done at +O0.)	Constant folding is the replacement of an operation on constant operands with result of the operation; constant propagation is the replacement of variable references with a constant value previously assigned to that variable
Loop invariant code motion	Recognizes instructions inside a loop where the results never change and moves those instructions outside the loop
Store/copy optimization	Substitutes registers for memory locations
Unused definition elimination	Removes unused references to memory locations and register definitions
Software pipelining	Re-arranges the order in which instructions execute in a loop to prevent processor stalls

Table 3 —(continued) Optimizations performed at +O2

Optimization	Description
Register reassociation	Reduces the cost of computing address expressions for array references by dedicating a register to track the value of the address expression
Loop unrolling	Increases a loop's step value and replicates the loop body, with each replication appropriately offset from the induction variable so that all iterations are performed given the new step.

+O3

At optimization level +O3, the following optimizations are made:

- The +O0, +O1, and +O2 optimizations
- Loop transformations such as distribution, interchange, fusion, vectorization, unrolling of non-innermost loops, directive-based blocking, and parallelization
- Hoisting conditional code out of loops (IF-DO interchange)
- Cloning within a file—Creating a specialized version of a subprogram that can be optimized on a per-call-site basis
- Subprogram inlining within a file

+O4

At this level, optimization occurs at link time, allowing the optimizer to analyze all files compiled with the +O4 option at once. Because analysis is done when linking, the compile time is generally shorter, but linking takes more time.

At optimization level +O4, the following optimizations are made:

- The +O0, +O1, +O2, and +O3 optimizations
- Cloning across all files in the program that have been compiled at +O4
- Inlining across all files in the program that have been compiled at +O4

+O[no]all

The +Oall option applies maximum optimization to achieve the best runtime performance. This option is equivalent to specifying +Oaggressive and +Onolimit on the same command line. The +Oall option implies +O4. The default is +Onoall.

+O[no]dataprefetch

The +O[no]dataprefetch option enables [disables] optimizations to generate data prefetch instructions for data structures referenced within innermost loops. The effect is that the memory system will be retrieving the data for future iterations while the processor is executing current iterations.

This option provides no benefit to loops whose data fits in the cache; in fact, it can slow them down, because of the prefetch instructions. For loops whose data does not fit in the cache, the speedup can be substantial. For information on a related option, see the section "+O[no]writeprefetch" on page 16.

The +O[no]dataprefetch option is valid at +O2 and above.

+O[no]fail_safe

The +Ofail_safe option allows a compilation with internal optimization errors to continue, rather than abort. If internal optimization errors are found, the compiler issues a warning message, then restarts the compilation at +O0. When using +Onofail_safe, compilation aborts if internal optimization errors occur.

This option can be used at +O1 or higher. The default is +Ofail_safe.

+O[no]info

The +O[no]info option displays [does not display] feedback information about the optimization process (for example, cloning and inlining). Currently, this option is useful only at +O3 and above. The default is +Onoinfo. For information on a related option, see the section "+O[no]report[=report_type]" on page 15.

+O[no]loop_transform

The +O[no]loop_transform option transforms [does not transform] eligible loops for improved cache performance. The transforms include loop distribution, loop interchange, and loop fusion. This option can be used at +O3 and above. The default is +Oloop_transform.

+O[no]limit

The +O[no]limit option suppresses [does not suppress] optimizations that significantly increase compile-time or consume large amounts of memory. This option can be used at +O2 and above. The default is +Olimit.

+O[no]loop_unroll[=*n*]

This option unrolls [does not unroll] program loops by a factor of *n*. For example, specifying +Oloop_unroll=4 requests the optimizer to replicate the loop body four times. This option can be used at +O2 and above. The default is +Oloop_unroll=4.

+O[no]parallel_env

This option compiles for a parallel [serial] execution environment. This option does not request parallelization for the target source; rather, it ensures a consistent execution environment for all files in a parallel-executing program. This option is only supported for applications using process-based parallelism. If you want to compile an application for process-based parallel execution, you must compile all of its files with either +Oparallel or +Oparallel_env.

Note

Do not use the +Oparallel_env option unless you are creating a process-based parallel application. Applications created using the Exemplar programming model are thread-based parallel.

Compiler usage

The examples below demonstrate the use of the `c89` and `f77` compilers. The functionality and options illustrated in any example apply to both the `c89` and `f77` compilers.

Using `c89`

The `c89` compiler command is located at /opt/ansic/bin/c89 and has the form:

`% c89 [`*options*`]` *files*

where

options

is one or more of the `c89` compiler options

files

is a space-delimited list of one or more files

For example, the following command

```
% c89 prog1.c prog2.c prog3.c
```

compiles the three files (prog1.c, prog2.c, prog3.c) and produces an executable, which is named a.out by default.

In the next example

```
% c89 prog.c proc1.o -o prog
```

`c89` compiles prog.c to produce the object file prog.o, then calls the linker `ld` to link prog.o and proc1.o with the default start-up routines and library routines. The file prog.o is deleted after linking. The `-o prog` causes the resulting executable file to be named prog instead of a.out.

The last example

```
% c89 -g +O0 prog.c
```

shows the debugging option (`-g`) and the request of level 0 optimizations (`+O0`).

For additional information, see the c89(1) man page.

Using f77

The f77 compiler command is located at /opt/fortran/bin/f77 and has the form:

% f77 [*options*] *files*

where

options

is one or more of the f77 compiler options

files

is a space-delimited list of one or more files

For example, the command

```
% f77 -c prog.f
```

compiles the file prog.f to produce the object file prog.o, then (because of the -c option) suppresses linking. The prog.o file can be linked later by including it on a f77 command line or by using the linker (ld) directly.

In the following example

```
% f77 -v prog1.f prog2.f
```

the verbose mode is enabled by using -v. When compiling in verbose mode, the compiler displays (to standard error) a step-by-step description of the compilation process.

The last example

```
% f77 +O3 +Oparallel prog.f
```

shows the request of level 3 optimizations (+O3) and the request that the compiler recognize the parallelism directives and pragmas of the Exemplar programming model (+Oparallel). The +Oparallel option is only valid at +O3 and above.

For additional information, see the f77(1) man page.

Options to get you started

This section highlights options that you may want to use regularly with the Exemplar compilers. The options are performance-related and are described only briefly in this section; however, sources for more information are included.

Table 4 Recommended options

Option	Description
`+DS2.0a`	Generate slightly faster code than `+DS2.0`.
`+DA2.0N`	Generate slightly faster code than `+DA2.0`.
`+O3`	Invoke level 3 optimizations. See the section "+O3" on page 5 for more information.
`+O3 +Oparallel`	Invoke level 3 optimizations and cause the compiler to recognize parallelism directives and pragmas from the Exemplar programming model*. See the section "+O[no]parallel" on page 14 for more information.
`+Odataprefetch`	Prefetch data for data structures referenced in loops. See the section "+O[no]dataprefetch" on page 6 for more information.
`+Oinfo`	Display information on the optimization process. See the section "+O[no]info" on page 6 for more information.
`+Olibcalls`	Use low-call-overhead versions of select library routines. See the c89(1) or the f77(1) man page for more information.
`+Oreport`	Display optimization reports. See the section "+O[no]report[=report_type]" on page 15 for more information.
`+Onolimit`	Do not suppress optimizations that significantly increase compile-time or consume large amounts of memory. See the section "+O[no]limit" on page 7 for more information.
`+Owriteprefetch`	Prefetch data for data structures referenced in loops, using instructions that inform the memory system whether a shared or private cache line is needed. See the section "+O[no]writeprefetch" on page 16 for more information.
`-Wl,-aarchive_shared`	(For use when linking with the compiler driver) Search the archive version of a library; if the archive version is not available, search the shared version of the library
`-Wl,+FPD`	(For use when linking with the compiler driver) Underflows are exceptions, by default; this option avoids exceptions so that underflows just generate zeros

*Assuming `+Onoexemplar_model` is not also specified

Exemplar extensions 2

This chapter describes options that are specific to the Exemplar compilers and explains how they are used. In addition, this chapter describes the available directives and pragmas. This chapter also discusses the Exemplar Fortran 77 language extensions and intrinsics. Finally, this chapter covers large files support and predefined C preprocessor symbols.

Exemplar compilers recognize the options, directives, and pragmas that the standard HP compilers recognize. Extensions accepted by the Exemplar compilers, however, are not recognized by the standard HP compilers. The following sections describe these extensions. See Chapter 1, "Introduction," for an overview of the standard HP compiler options discussed below.

Exemplar compiler options

The options below are recognized in addition to those supported by the standard HP compilers or are available in the standard HP compilers but have been modified to behave differently in the Exemplar compilers.

-g (available only at +O0)

This option requests that the compiler generate debugging information in the executable file that can be used by the CXdb debugger (an optional product). See Chapter 5, "Debugging and profiling," for more information on CXdb. (Debugging with the dde and xdb debuggers is not supported on S-Class and X-Class servers.)

The `-g` option is ignored at optimization levels greater than `+O0`. Also, `-g` is ignored with `-O` because it implies `+O2`.

-I8

This option specifies that INTEGER and LOGICAL variable declarations with unspecified lengths are to occupy 8 bytes of storage.

Also, this option transforms intrinsic function references that return default integer or logical values to return 8-byte values of the specified type.

+Okernel_threads (default)

The +Okernel_threads option causes the compiler to use a thread-based model of parallelism. The Exemplar programming model requires thread-based parallelism. This option is available at all optimization levels.

+O[no]autopar

Because parallelization takes places only at +O3 and above, +O[no]autopar is useful only at +O3 and above. The default is +Oautopar.

When used with +Oparallel option, +Oautopar causes the compiler to automatically parallelize loops that are safe to parallelize. (A loop is safe to parallelize if it has an iteration count determinable at runtime before loop invocation, and contains no loop-carried dependences, procedure calls, or I/O operations. A loop-carried dependence exists when one iteration of a loop assigns a value to an address that is referenced or assigned on another iteration.) You can use Fortran directives and C pragmas to improve on the automatic optimizations and to assist the compiler in locating additional opportunities for parallelization.

When used with +Oparallel, the +Onoautopar option causes the compiler to parallelize only those loops marked by the loop_parallel or prefer_parallel directives or pragmas.

+O[no]dynsel

When specified with +Oparallel, +Odynsel enables workload-based dynamic selection. This optimization causes the compiler to generate parallel and serial versions of parallelizable loops whose iteration counts are unknown at compile time. At runtime, the loop's workload is compared to parallelization overhead, and the parallel version is run only if it is profitable to do so.

The +Onodynsel option disables dynamic selection and tells the compiler that it is profitable to parallelize all parallelizable loops. The dynsel directive and pragma can be used to enable dynamic selection for specific loops when +Onodynsel is in effect.

+O[no]exemplar_model

+Oexemplar_model (the default) causes the compiler to accept the Exemplar programming model. This option allows you to use the directives, pragmas, and associated command-line options that make up the programming model. At lower optimization levels (+O0, +O1, +O2), this option enables only the following components of the programming model:

- Synchronization directives (Fortran)
- Synchronization pragmas and synchronization typedefs (C)
- Memory class directives (Fortran)
- Memory storage class specifiers (C)

At +O3 and +O4, using +Oexemplar_model enables all directives, pragmas, storage class specifiers, and typedefs. See the section "Exemplar compiler directives and pragmas" on page 17 for additional information.

The +Oexemplar_model option implies the +Okernel_threads option.

The +Onoexemplar_model option turns off support for the Exemplar programming model. If you use this option, directives and pragmas from the Exemplar programming model will be ignored.

+O[no]parallel

The +Onoparallel option is the default for all optimization levels. This option disables automatic, directive-specified, and pragma-specified parallelization.

The +Oparallel option causes the compiler to

- Recognize the directives and pragmas of the Exemplar programming model that involve parallelism, such as begin_tasks, loop_parallel, and prefer_parallel.
- Look for opportunities for parallel execution in loops. If the environment variable MP_NUMBER_OF_THREADS is set to some integer *n*, the compiler generates parallel code to execute loops on *n* processors. If MP_NUMBER_OF_THREADS is not set, the compiler generates parallel code to execute loops on the number of processors in the subcomplex where the application is executing.This variable is used at runtime.

  The mpa utility can be used in this capacity as well; see the section "Using the mpa utility" on page 59 for more information.

The +Oparallel option is valid only at optimization level +O3 and above. Using this option disables +Ofail_safe, which is on by default. See the section "+O[no]fail_safe" on page 6 for more information.

Note

If you compile one file in an application using +Oparallel, then the application must be linked (using the compiler driver) with the +Oparallel option specified to link in the proper start-up files and runtime support.

+O[no]report[=*report_type*]

This option causes the compiler to display various optimization reports. `+Onoreport` is the default. The value of *report_type* determines which report is displayed, as described below.

`+Oreport=loop` produces the Loop Report. This report gives information on optimizations performed on loops and calls. Using `+Oreport` (without =*report_type*) also produces the Loop Report.

`+Oreport=private` produces the Loop Report and the Privatization Report, which provides information on loop variables that are privatized by the compiler.

`+Oreport=all` produces all reports.

The `+Oreport[=`*report_type*`]` option is active only at `+O3` and above. See the *Exemplar Programming Guide* for more information on the optimization reports.

The option `+Oinfo` displays additional information on the various optimizations being performed by the compilers. `+Oinfo` can be used at any optimization level but is most useful at `+O3` and above. The default, at all optimization levels, is `+Onoinfo`.

+O[no]sharedgra

The `+Onosharedgra` option disables global register allocation for shared-memory variables that are visible to multiple threads. This option may help if a variable shared among parallel threads is causing wrong answers. See the *Exemplar Programming Guide* for more information.

Global register allocation is enabled by default at optimization level `+O2` and higher; that is, `+Osharedgra` is the default and is available at `+O2` and above.

+pa (+O0, +O1, +O2)

The `+pa` option requests that the compiler add instrumentation (additional information) to an executable file for the CXpa performance analyzer to read. The `+pa` option is not valid at optimization levels greater than `+O2`. Also, `+pa` is not compatible with the `-p` or `-G` options. See Chapter 5, "Debugging and profiling," for more information on CXpa.

+Oprocess_threads

The +Oprocess_threads option causes the compiler to use process-based parallelism. Process-based parallelism is used by the standard HP compilers.

This option implies +Onoexemplar_model. If you use the +Oprocess_threads option, directives and pragmas from the Exemplar programming model will be ignored. If +Oexemplar_model and +Oprocess_threads are both specified, +Oprocess_threads is ignored with a warning, and +Okernel_threads is selected.

+O[no]writeprefetch

This option is similar to +Odataprefetch, but causes the prefetching code to use instructions that inform the memory system whether a shared or private cache line is needed. It is generally true that +Owriteprefetch performs better than +Odataprefetch. The default is +Onowriteprefetch.

The +O[no]writeprefetch option is valid at +O2 and above.

+tm *target*

This option specifies the target machine architecture for which compilation is to be performed. *target* takes one of the following values:

- spp1200 to specify SPP1200 Series machines
- spp1600 to specify SPP1600 Series machines
- S2000 to specify S-Class 2000 servers
- X2000 to specify X-Class 2000 servers

The default *target* value corresponds to the machine on which you invoke the compiler.

Exemplar compiler directives and pragmas

This section presents an alphabetical list of the Fortran directives and C pragmas that make up the Exemplar programming model. The Exemplar compilers accept the directives and pragmas listed below in addition to those supported by the standard HP compilers.

This section is intended to provide only a brief overview of the available directives and pragmas. More specific information and examples can be found in the *Exemplar Programming Guide*. The Fortran directives not supported as C pragmas are expressed in C as either storage class extensions (`thread_private`, etc.) or as typedefs (`gate_t`, `barrier_t`, etc.) in the spp_prog_model.h file and are described in the "Memory classes" and the "Advanced shared-memory programming" chapters of the *Exemplar Programming Guide*.

The form of an Exemplar Fortran compiler directive is:

`C$DIR` *directive-specification*

The form of an Exemplar C pragma is:

`#pragma _CNX` *directive-specification*

where

directive-specification

is one of the directives/pragmas described in this chapter.

For information on how to properly use these directives or pragmas, see the *Exemplar Programming Guide*.

Directive names are presented here in lowercase; they may be specified in either case in both languages, but `#pragma` must always appear in lowercase in C. In the sections that follow, *namelist* represents a comma-delimited list of names. These names can be variables, arrays, or `COMMON` blocks. In the case of a `COMMON` block, its name must be enclosed within slashes. The occurrence of a lowercase *n* or *m* is used to indicate an integer constant. Occurrences of *gate_var* are for variables that have been, or are being, defined as gates. Any parameters that appear within square brackets ([ ]) are optional.

`barrier(`*namelist*`)`

This Fortran directive denotes a list of variables, as given in *namelist*, that are to be used as the synchronization variables for the barrier routines. This does not imply any synchronization in itself; it is simply defining the barrier variables. In C, `barrier` is a typedef (`barrier_t`), rather than a pragma. For more information, refer to the *Exemplar Programming Guide*.

`begin_tasks[(`*attribute_list*`)]`

This directive/pragma defines the beginning of a section (or sections; see `next_task`) of code that is to be executed as an independent, parallel task. Each task is executed by a separate thread. `begin_tasks` must have an accompanying `end_tasks` in the same program unit.

The optional *attribute_list* can be any of the following legal combinations (*m* is an integer constant):

- `max_threads=`*m*
- `ordered`
- `nodes`
- `threads`
- `ordered,nodes`
- `ordered,threads`
- `ordered,max_threads=`*m*
- `nodes,max_threads=`*m*
- `threads,max_threads=`*m*
- `ordered,nodes,max_threads=`*m*
- `ordered,threads,max_threads=`*m*

Attributes may be listed in any order. Any attribute combinations other than those listed above are flagged with a fatal error by the compilers.

Refer to the *Exemplar Programming Guide* for a complete discussion of parallel tasking.

`block_loop[(block_factor=n)]`

This directive/pragma indicates a specific loop to block, and optionally, the block factor *n* (*n* must be an integer constant greater than or equal to 2) that is to be used in the compiler's internal computation of loop nest based data reuse. If no `block_factor` is specified, a default `block_factor` of 32 is used. Refer to the *Exemplar Programming Guide* for more information on blocking.

`critical_section[(gate_var)]`

This directive/pragma defines the beginning of a code block in which only one thread may be executing at a time. The end of the code block must be indicated by an `end_critical_section` directive or pragma, which must appear in the same flow of control within the same program unit. The optional *gate_var* can be used to differentiate between parallel tasks. Refer to the *Exemplar Programming Guide* for more information.

`dynsel[(trip_count=n)]`

This directive/pragma enables workload-based dynamic selection for the immediately following loop. *trip_count* represents either the `thread_trip_count` or `node_trip_count` attribute, and *n* is an integer constant. When `thread_trip_count = n` is specified, the serial version of the loop is run if the iteration count is less than *n*; otherwise, the thread-parallel version is run. When `node_trip_count = n` is specified, the serial version of the loop is run if the iteration count is less than *n*; otherwise, the node-parallel version is run. *n* must be a compile-time constant.

`end_critical_section`

This directive/pragma defines the end of the critical section that was begun with the `critical_section` directive or pragma. `critical_section` and `end_critical_section` must appear as a pair. Refer to the *Exemplar Programming Guide* for more information.

`end_ordered_section`

This directive/pragma defines the end of the ordered section that was begun with the `ordered_section` directive or pragma. `ordered_section` and `end_ordered_section` must appear as a pair. Refer to the *Exemplar Programming Guide* for more information on ordered sections.

`end_tasks`

This directive/pragma terminates the specification of parallel tasks indicated by `begin_tasks` and `next_task`. It must appear at the end of the last section of parallel code defined by these directives or pragmas. All of these must appear in the same program unit. Refer to the *Exemplar Programming Guide* for more information.

`far_shared(`*namelist*`)`

This Fortran directive causes the compiler to place the data objects in *namelist* (variables, arrays, or `COMMON` blocks) into `far_shared` memory. `far_shared` memory is the most general form that is distributed on a page basis across the memories of all hypernodes in a subcomplex. (A hypernode is a set of processors and physical memory organized as a symmetric multiprocessor, or SMP, running a single image of the operating system microkernel.) The `far_shared` data objects of a process are addressable by all threads of that process. In C, `far_shared` is a storage class specifier. Refer to the *Exemplar Programming Guide* for more information on memory classes.

`gate(`*namelist*`)`

This Fortran directive defines a gate variable that is to be used subsequently in a critical section, ordered section, or passed as an argument to the synchronization intrinsics. In C, `gate` is a typedef (`gate_t`), rather than a pragma. Refer to the *Exemplar Programming Guide* for more information.

`loop_parallel [(attribute_list)]`

This directive/pragma is an explicit instruction to the compiler to parallelize the immediately following loop. The loop iterations are run in an indeterminate order unless the optional `ordered` attribute appears. You are responsible for any required data privatization and loop synchronization, as described in Chapter 4, "Basic shared-memory programming," and Chapter 6, "Advanced shared-memory programming," of the *Exemplar Programming Guide.* The optional *attribute_list* can be any of the following combinations (*n* and *m* are integer constants):

- `chunk_size=`*n*
- `max_threads=`*m*
- `ordered`
- `threads`
- `ordered,threads`
- `threads,chunk_size=`*n*
- `chunk_size=`*n*`,max_threads=`*m*
- `ordered,max_threads=`*m*
- `threads,max_threads=`*m*
- `ordered,threads,max_threads=`*m*
- `threads,chunk_size=`*n*`,max_threads=`*m*
- `ivar = `*indvar*

`ivar = `*indvar* is:

- Required for all loops in C and for `DO WHILE` and hand-rolled loops in Fortran
- Optional for Fortran `DO` loops
- Compatible with any other attribute

Attributes may be listed in any order. Any attribute combinations other than those listed above are flagged with a fatal error by the compilers.

Refer to the *Exemplar Programming Guide* for more information.

`loop_private(`*namelist*`)`

This directive/pragma declares a list of variables and/or arrays private to the immediately following loop. No values may be carried into the loop by `loop_private` variables.To be loop private, the variables and/or arrays must be assigned before they are used on any iteration of the immediately following loop. These private data items are distinct from the shared items of the same name that exist outside the loop. Values assigned to `loop_private` variables on the final iteration (that is, the *n*th iteration of a loop with *n* iterations) may be saved into the shared variables of the same name if the `save_last` directive or pragma also appears on this loop. If `save_last` is not used, then the value of any shared variable declared to be `loop_private` is undefined at loop termination. Refer to the *Exemplar Programming Guide* for more information.

`near_shared(`*namelist*`)`

When applied to static variables at compile-time, this Fortran directive causes all pages of the data objects in *namelist* to be mapped to physical pages on logical hypernode 0 (the hypernode where the program starts). If applied to allocatable arrays, then the pages of such arrays will be mapped to physical pages on the hypernode of the allocating thread. `near_shared` data can be addressed by any thread of a process on any hypernode in the subcomplex but it is "closer" (in terms of access latency) to the threads on the hypernode that allocates the data. In C, `near_shared` is a storage class specifier. Refer to the *Exemplar Programming Guide* for more information on memory classes.

`next_task`

This directive/pragma starts a block of code following a `begin_tasks` block that will be executed as a parallel task. The end of the code block is marked by another `next_task` or by an `end_tasks` directive or pragma.

This directive must appear within a `begin_tasks` and `end_tasks` pair. There is no limit on the number of `next_task` directives that can appear. Refer to the *Exemplar Programming Guide* for more information.

no_block_loop

This directive/pragma disables loop blocking on the immediately following loop. Refer to the *Exemplar Programming Guide* for more information on loop blocking.

no_distribute

This directive/pragma disables loop distribution for the immediately following loop. Refer to the *Exemplar Programming Guide* for more information on loop distribution.

no_dynsel

This directive/pragma disables workload-based dynamic selection for the immediately following loop. Refer to the *Exemplar Programming Guide* for more information on dynamic selection.

no_loop_dependence(*namelist*)

This directive/pragma informs the compiler that the arrays in *namelist* do not have any dependences for iterations of the immediately following loop. Use `no_loop_dependence` for arrays only; use `loop_private` to indicate dependence-free scalar variables.

This causes the compiler to ignore any dependences that it perceives to exist. This can enhance the compiler's ability to optimize the loop, including the possibility of parallelization.

Refer to the *Exemplar Programming Guide* for more information.

no_parallel

This directive/pragma prevents the compiler from generating parallel code for the immediately following loop. Refer to the *Exemplar Programming Guide* for more information.

`no_side_effects(`*funclist*`)`

This directive/pragma informs the compiler that the functions appearing in *funclist* have no side effects wherever they appear lexically following the directive. Side effects include modifying a function argument, modifying a Fortran COMMON variable, performing I/O, or calling another routine that does any of the above. The compiler can sometimes eliminate calls to procedures that have no side effects; also, the compiler may be able to parallelize loops with calls when informed that the called routines do not have side effects.

`ordered_section[(`*gate_var*`)]`

This directive/pragma defines the beginning of an ordered section. An ordered section is the same as a critical section (a code block in which only one thread may be executing at a time) with the additional restriction that the threads must pass through the ordered section in iteration order. The end of the code block must be indicated by an `end_ordered_section` directive or pragma. Ordered sections must appear within the control flow of a `loop_parallel(ordered)` directive. Refer to the *Exemplar Programming Guide* for more information.

`prefer_parallel[(attribute_list)]`

This directive/pragma instructs the compiler to parallelize the following loop, but only if it is safe to do so. A loop is safe to parallelize if it has an iteration count determinable at runtime before loop invocation and contains no loop-carried dependences, procedure calls, or I/O operations. (A loop-carried dependence exists when one iteration of a loop assigns a value to an address that is referenced or assigned on another iteration.) Refer to the *Exemplar Programming Guide* for more information.

The optional *attribute_list* can be any of the following combinations (*n* and *m* are integer constants):

- `chunk_size=`*n*
- `max_threads=`*m*
- `ordered`
- `threads`
- `ordered,threads`
- `threads,chunk_size=`*n*
- `chunk_size=`*n*`,max_threads=`*m*
- `ordered,max_threads=`*m*
- `threads,max_threads=`*m*
- `ordered,threads,max_threads=`*m*
- `threads,chunk_size=`*n*`,max_threads=`*m*

Attributes may be listed in any order. Any attribute combinations other than those listed above are flagged with a fatal error by the compilers.

`save_last`

This directive/pragma specifies that all variables named in an associated `loop_private(`*namelist*`)` directive/pragma must have their last values (a variable's last value in a loop of *n* iterations is its value that is generated in the *n*th iteration) saved into the "shared" variable of the same name, at loop termination. If `save_last` is not specified then the values in any privatized variables or arrays are indeterminate at loop termination. Refer to the *Exemplar Programming Guide* for more information.

`scalar`

This directive prevents the compiler from performing reordering transformations on the following loop. The compiler does not parallelize or data-localize a loop on which this directive appears.

`sync_routine(`*routinelist*`)`

This directive/pragma indicates to the compiler that the routines listed in *routinelist* are user-defined synchronization routines, so that the compiler does not attempt to move code across these routine calls. Use `sync_routine` anytime you hide a call to a compiler synchronization function inside another routine call, or anytime you use CPSlib functions for synchronization. (CPSlib is a library of low-level parallelization and synchronization routines. See the *Exemplar Programming Guide* for more information.)

`sync_routine` is effective only for the listed routines in the file in which it appears.

`task_private(`*namelist*`)`

This directive/pragma privatizes the variables and arrays specified in *namelist* for each task specified in the immediately following `begin_tasks/end_tasks` block. The privatized variables and arrays do not carry their values beyond the `end_tasks` directive or pragma. Refer to the *Exemplar Programming Guide* for more information.

`thread_private(`*namelist*`)`

This Fortran directive causes the variables and arrays specified in *namelist* to be treated (by software convention) as being `thread_private`. `thread_private` data objects map to unique `node_private` addresses for each thread of a process. In C, `thread_private` is a storage class specifier. Refer to the *Exemplar Programming Guide* for more information.

Exemplar Fortran language extensions

This section describes the Fortran 77 extensions that are supported in the Exemplar `f77` compiler. See the *HP FORTRAN/9000 Programmer's Reference* for information on the extensions available in the standard HP Fortran compiler.

INTEGER*8

Allocates storage for 8-byte integer data.

LOGICAL*8

Allocates storage for 8-byte logical data.

TASK COMMON

Exemplar Fortran supports Cray TASK COMMON blocks. A program should already be running multiple threads before calling a subroutine that contains a TASK COMMON block.

On S-Class and X-Class servers, variables in a TASK COMMON block are stored in a thread-private COMMON block (each thread has its own thread-local copy of the TASK COMMON block).

The TASK COMMON statement creates these blocks and has the form:

TASK COMMON */cbn/nlist* [, */cbn/nlist*] . . .

where

cbn

is a symbolic name for a TASK COMMON block. Unnamed TASK COMMON blocks are not allowed.

nlist

is a list of variable names, array names, and array declarators. These variables cannot appear in a DATA statement, but otherwise can be used like any variables in COMMON storage.

All occurrences of the TASK COMMON block must be declared TASK COMMON; a COMMON block cannot be declared both COMMON and TASK COMMON. TASK COMMON blocks can be declared only in functions, subprograms and BLOCK DATA subprograms.

Exemplar Fortran intrinsics

Table 5 describes the intrinsics in Exemplar Fortran that support INTEGER*8 data.

Table 5 Intrinsic functions

Entry point	Description	Specific intrinsic
BTEST_8	Bit test of an integer value	`LOGICAL(8) function BKTEST(I,POS)` `INTEGER(8) :: I,POS`
FTN_KQNINT	Nearest integer	`INTEGER(8) function KIQNNT(A)` `REAL(16) :: A`
FTN_KSIGN	Absolute value of A times B	`INTEGER(8) function KISIGN(A,B)` `INTEGER(8) :: A,B`
FTN_KZEXT_B1	Zero extend	`INTEGER(8) function KZEXT(A)` `LOGICAL(8) :: A`
IBCLR_8	Clear a bit to zero	`INTEGER(8) function KIBCLR(I,POS)` `INTEGER(8) :: I,POS`
IBITS_8	Extract a sequence of bits	`INTEGER(8) function KIBITS(I,POS,LEN)` `INTEGER(8) :: I,POS,LEN`
IBSET_8	Set a bit to one	`INTEGER(8) function KIBSET(I,POS)` `INTEGER(8) :: I,POS`
ISHFT_8	Logical shift	`INTEGER(8) function KISHFT(I,SHIFT)` `INTEGER(8) :: I,SHIFT`

ISHFTC_8	Circular shift of rightmost bits	`INTEGER(8) function KISHFTC(I,SHIFT,SIZE)`
		`INTEGER(8) :: I,SHIFT`
		`INTEGER(8),OPTIONAL :: SIZE`

KABS	Integer absolute value	`INTEGER(8) function KIABS(A)` `INTEGER(8) :: A`
KDIM	Positive difference	`INTEGER(8) function KIDIM(X,Y)` `INTEGER(8) :: X,Y`
KIDNINT	Nearest integer	`INTEGER(8) function KIDNNT(A)` `DOUBLE PRECISION:: A`
KININT	Nearest integer	`INTEGER(8) function KNINT(A)` `REAL :: A`
KMOD	Remainder function	`INTEGER(8) function KMOD(A,P)` `INTEGER(8) :: A,P`

MVBITS_8	Copy a sequence of bits from one data object to another	`subroutine KMVBITS(FROM,FROMPOS,LEN,TO,TOPOS)`
		`INTEGER(8):: FROM,TO`
		`INTEGER :: FROMPOS, TOPOS, LEN`

Predefined symbols

The items listed in this section are predefined and have special meanings.

Note

"__" indicates two adjacent underscore characters. There is no space between these characters. If a space is added, the compiler does not recognize the variable as a predefined symbol.

`__HP_CXD_SPP=1`

This symbol (which has two leading underscores) is always defined when using the Exemplar compilers. The preprocessor (cpp) predefines this symbol so that code can be conditionalized based on whether a file is being compiled using the Exemplar compilers.

`_REENTRANT=1`

This symbol (which has one leading underscore) is predefined for use by the include files. When it is predefined, reentrant versions of libc routines are called. When `_REENTRANT` is not predefined, some libc routines that are not reentrant are called. Calling a non-reentrant routine from within a parallel region is an error.

The compiler predefines this symbol if `+Oparallel` is specified with either `+O3` or `+O4`.

Large files support

The SPP-UX operating system and the Exemplar compilers support *large files*. A large file is a file that is greater than $2^{31} - 1$ bytes in size (approximately 2 gigabytes).

Several SPP-UX utilities have been modified to function properly on large files. See the largefiles(1m) man page for information on the modified utilities and on compiler support for large files.

Migrating to the Exemplar compilers

3

This chapter provides transition information for users moving from the SPP1000-Series compilers (/usr/convex/bin/cc, /usr/convex/bin/fc) to the Exemplar compilers, which are based on the standard HP compilers. Options, directives, and pragmas available in the SPP1000-Series compilers are mapped to the equivalent features in the Exemplar compilers. In addition, this chapter lists the language extensions from the SPP1000-Series compilers that the Exemplar compilers support. Finally, this chapter covers changes in accessing CPSlib.

Compiler options

This section lists the compiler options from the SPP1000-Series compilers that are supported by the Exemplar compilers or are obsolete.

In Table 6, the compiler options in the left column are from the SPP1000-Series compilers (/usr/convex/bin/cc, /usr/convex/bin/fc). The middle column lists corresponding or similar options in the Exemplar compilers (/opt/ansic/bin/c89, /opt/fortran/bin/f77) or states that the option is obsolete. The right column points to additional information on the Exemplar compiler options.

Note

Functionality may differ between corresponding options.

The following table does not list options (such as -o and -c) that are common across a number of compilers.

Table 6 Mapping of compiler options

SPP1000-Series compiler option*	Exemplar compiler option	For more information, see...
-72	Default	
-a1	*obsolete option*	
-alias addr	*obsolete option*	
-alias array_args	+Onoparmsoverlap	c89(1) man page
-alias cautious	*obsolete option*	
-alias global	+Optrs_to_globals	c89(1) man page
-alias no_addr	*obsolete option*	
-alias no_global	+Onoptrs_to_globals	c89(1) man page
-alias ptr_args	*obsolete option*	
-alias restrict_args	*obsolete option*	
-alias standard	+Optrs_strongly_typed	c89(1) man page
-alias worst	+Onoptrs_ansi	c89(1) man page
-align cache	*obsolete option*	
-align cache_check	*obsolete option*	
-align cseries	*obsolete option*	
-align cti	*obsolete option*	
-align spp	+A8 (Fortran only)	f77(1) man page

Table 6 —(continued) Mapping of compiler options

SPP1000-Series compiler option*	Exemplar compiler option	For more information, see...
`-ansi77`	`-A`	f77(1) man page
`-ansi90`	*obsolete option*	
`-blockloop` *n*	*obsolete option*	
`-br`	*obsolete option*	
`-cache` *n*	*obsolete option*	
`-cfc`	Cray Fortran extensions are enabled by default	
`-com`	similar to `-v`	c89(1) man page, f77(1) man page
`-cs`	`-C`	f77(1) man page
`-ctifiles`	*obsolete option*	
`-cxdb`	`-g`	Chapter2, "Exemplar extensions"
`-cxpa`	`+pa`	Chapter2, "Exemplar extensions"
`-cxpab`	*obsolete option*	
`-cxpalib`	*obsolete option*	
`-cxpamon`	*obsolete option*	
`-cxpar`	`+pa`	Chapter2, "Exemplar extensions"
`-d` *name* `[={w|e}]`	*obsolete option*	
`-dc`	`-D`	f77(1) man page
`-ds`	`+Odynsel`	Chapter2, "Exemplar extensions"
`-errnames`	*obsolete option*	
`-ext`	similar to `-Ae`	c89(1) man page
`-extern distinct`	*obsolete option*	
`-extern same`	Default	
`-F66`	`-w66`	f77(1) man page
`-fd`	see `+f` and `+r`	c89(1) man page

Table 6 —(continued) Mapping of compiler options

SPP1000-Series compiler option*	Exemplar compiler option	For more information, see...
`-fl`	`+Oloop_transform`	Chapter1, "Introduction"
`-float dp_const`	*obsolete option*	
`-float sp_const`	see `+f` and `+r`	c89(1) man page
`-float dp_ops`	*obsolete option*	
`-float sp_ops`	see `+f` and `+r`	c89(1) man page
`-gs`	`+Osharedgra`	Chapter2, "Exemplar extensions"
`-i1`	*obsolete option*	
`-i2`	`-I2`	f77(1) man page
`-i4`	`-I4`	f77(1) man page
`-i8`	`-I8`	Chapter2, "Exemplar extensions"
`-il`	*obsolete option*	
`-ipo`	`+O4`	Chapter1, "Introduction"
`-is` *directory*	*obsolete option*	
`-LST`	`-L`	f77(1) man page
`-LSTI`	*obsolete option*	
`-mo`	similar to `+Onofltacc`	c89(1) man page, f77(1) man page
`-mrl`	similar to `+Onolimit`	c89(1) man page, f77(1) man page
`-na`	*obsolete option*	
`-nbr`	*obsolete option*	
`-nds`	`+Onodynsel`	Chapter2, "Exemplar extensions"
`-nfl`	`+Onoloop_transform`	c89(1) man page, f77(1) man page
`-nga`	*obsolete option*	
`-ngr`	*obsolete option*	

Table 6 —(continued) Mapping of compiler options

SPP1000-Series compiler option*	Exemplar compiler option	For more information, see...
-ngs	+Onosharedgra	Chapter2, "Exemplar extensions"
-nmo	similar to +Ofltacc	c89(1) man page, f77(1) man page
-no	+O0 (default)	Chapter1, "Introduction"
-noautopar	+Onoautopar	Chapter2, "Exemplar extensions"
-noblock	*obsolete option*	
-nof90	*obsolete option*	
-nopeel	*obsolete option*	
-noptst	*obsolete option*	
-nore	*obsolete option*	
-nosc	*obsolete option*	
-noU77	Default (Use +U77 to get libU77 routines.)	f77(1) man page
-nptr	*obsolete option*	
-nsr	*obsolete option*	
-nuj	*obsolete option*	
-nur	+Onoloop_unroll	Chapter1, "Introduction"
-nv	Default is no report	
-nw	-w	c89(1) man page, f77(1) man page
-O (same as -O2)	-O (same as +O2)	Chapter1, "Introduction"
-O0	*obsolete option*	
-O1	similar to +O2	Chapter1, "Introduction"
-O2	similar to +O3	Chapter1, "Introduction"
-O3	similar to +O3 +Oparallel	Chapter2, "Exemplar extensions"

Table 6 —(continued) Mapping of compiler options

SPP1000-Series compiler option*	Exemplar compiler option	For more information, see...
`-or` *table*	`+Oreport[=`*report_type*`]`	Chapter2, "Exemplar extensions"
`-p`	`-p` (Using `prof` for multithreaded applications is not supported on S-Class and X-Class servers.)	
`-p8`	`$AUTODBL DBL` source code directive	*HP FORTRAN/9000 Programmer's Reference*
`-parens explicit`	*obsolete option*	
`-parens ignore`	*obsolete option*	
`-parens implicit`	*obsolete option*	
`-pcc`	`-Ac`	c89(1) man page
`-pd8`	similar to `-I8` with `$AUTODBL DBL DBL4` source code directive	*HP FORTRAN/9000 Programmer's Reference,* and "-I8" on page 34
`-peel`	*obsolete option*	
`-peelall`	*obsolete option*	
`-pg`	`-G` (Using `gprof` for multithreaded applications is not supported on S-Class and X-Class servers.)	
`-pl` *n*	`$LINES` *n* source code directive	*HP FORTRAN/9000 Programmer's Reference*
`-ppu`	`+ppu`	f77(1) man page
`-ptst`	*obsolete option*	
`-ptstall`	*obsolete option*	
`-pw` *n*	*obsolete option*	
`-r4`	`-R4`	f77(1) man page
`-r8`	`-R8`	f77(1) man page
`-re`	*obsolete option*	
`-sc`	*obsolete option*	
`-sfc`	Sun Fortran extensions are enabled by default	

Table 6 —(continued) Mapping of compiler options

SPP1000-Series compiler option*	Exemplar compiler option	For more information, see...
`-sr`	*obsolete option*	
`-std`	`-Aa`	c89(1) man page
`-string read_only`	`+ESlit`	c89(1) man page
`-string write_only`	Default	
`-tm` *target*	`+tm` *target*	Chapter2, "Exemplar extensions"
`-tri off`	*obsolete option*	
`-tri on`	Default	
`-uj`	*obsolete option*	
`-ujn` *n*	*obsolete option*	
`-uo`	*obsolete option*	
`-ur`	`+Oloop_unroll`	Chapter1, "Introduction"
`-urn` *n*	`+Oloop_unroll=`*n*	Chapter1, "Introduction"
`-vfc`	VAX Fortran extensions are enabled by default	
`-vn`	Use the `what` command on the executable to display version info for the Exemplar compilers.	what(1) man page
`-xr`	`+R`	f77(1) man page
`-xra`	*obsolete option*	

*SPP1000-Series compiler refers to /usr/convex/bin/cc and /usr/convex/bin/fc

Directives and pragmas

This section lists the directives and pragmas from the SPP1000-Series compilers (/usr/convex/bin/cc and /usr/convex/bin/fc) that are supported by the Exemplar compilers or are obsolete.

The forms of the directives and pragmas in the SPP1000-Series compilers are accepted by the Exemplar compilers.

The form of an SPP1000-Series Fortran compiler directive is:

`C$DIR [CSERIES|SPP]` *directive-specification*

The form of an SPP1000-Series C pragma is:

`#pragma _CNX [CSERIES|SPP]` *directive-specification*

If `CSERIES` is specified, the directive is discarded by the compiler. See the section "Exemplar compiler directives and pragmas" on page 17 for information on the recommended forms for the Exemplar compilers.

Table 7 lists the compiler directives and pragmas and states whether they exist in the Exemplar compilers. Words in *italics* indicate user-supplied information. For the directives and pragmas that are implemented, descriptions are given in Chapter 2. However, for more information on using the directives and pragmas, see the *Exemplar Programming Guide*.

Table 7 Compiler directives/pragmas

Directive/pragma	Status
`barrier` (*namelist*) directive in Fortran `barrier_t` typedef in C	Implemented*
`begin_tasks` [(*attribute_list*)]	Implemented*
`block_loop` [(`block_factor=`*n*)]	Implemented*
`critical_section`[(*gate_var*)]	Implemented*
`dynsel` [(*trip_count=n*)]	Implemented*
`end_critical_section`	Implemented*
`end_ordered_section`	Implemented*
`end_tasks`	Implemented*
`far_shared` (*namelist*) directive in Fortran `far_shared` storage class specifier in C	Implemented*
`gate` (*namelist*) directive in Fortran `gate_t` typedef in C	Implemented*
`loop_parallel` [(*attribute_list*)]	Implemented*
`loop_private` (*namelist*)	Implemented*
`near_shared` (*namelist*) directive in Fortran `near_shared` storage class specifier in C	Implemented*
`next_task`	Implemented*
`no_block_loop`	Implemented*
`no_distribute`	Implemented*
`no_dynsel`	Implemented*
`no_fuse`	Obsolete directive/pragma
`no_loop_dependence` (*namelist*)	Implemented*
`no_parallel`	Implemented*
`no_peel`	Obsolete directive/pragma
`no_promote_test`	Obsolete directive/pragma

Table 7 —(continued) Compiler directives/pragmas

Directive/pragma	Status
`no_side_effects` (*funclist*)	Implemented*
`no_unroll`	Obsolete directive/pragma
`no_unroll_and_jam`	Obsolete directive/pragma
`node_private` (*namelist*) directive in Fortran `node_private` storage class specifier in C	Implemented*
`opt_level` (*level*)	Obsolete directive/pragma
`ordered_section` [(*gate_var*)]	Implemented*
`peel`	Obsolete directive/pragma
`peel_all`	Obsolete directive/pragma
`prefer_fuse`	Obsolete directive/pragma
`prefer_parallel` [(*attribute_list*)]	Implemented*
`promote_test`	Obsolete directive/pragma
`promote_test_all`	Obsolete directive/pragma
`row_wise`	Obsolete directive/pragma
`save_last`	Implemented*
`scalar`	Implemented in Fortran*
`sync_routine` (*routinelist*)	Implemented*
`task_private` (*namelist*)	Implemented*
`thread_private` (*namelist*) directive in Fortran `thread_private` storage class specifier in C	Implemented*
`unroll` [(`unroll_factor=`*n*)]	Obsolete directive/pragma
`unroll_and_jam` [(`unroll_factor=`*n*)]	Obsolete directive/pragma

* For more information on implemented directives and pragmas, see Chapter 2, "Exemplar extensions".

Fortran 77 language extensions

This section lists the Fortran 77 language extensions from the SPP1000-Series Fortran compiler (/usr/convex/bin/fc) that are supported by the Exemplar Fortran compiler or are obsolete.

Table 8 lists the Fortran 77 extensions that are supported in the Exemplar `f77` compiler. Because these extensions are available in the standard HP Fortran compiler, the functionality may differ slightly from the SPP1000-Series Fortran compiler. Unless noted otherwise, see *HP FORTRAN/9000 Programmer's Reference* for information on using these extensions.

Table 8 Fortran 77 language extensions

Extension	Status
$ edit descriptor	Implemented
* edit descriptor	Obsolete extension
%REF	Implemented
%VAL	Implemented
.XOR.	Implemented
ACCEPT	Implemented
ALLOCATABLE	Implemented
ALLOCATE	Implemented
AUTOMATIC	Implemented
BLOCKSIZE keyword	Implemented
BUFFERIN	Obsolete extension
BUFFEROUT	Obsolete extension
CARRIAGECONTROL keyword	Implemented
COMPLEX*8	Implemented
COMPLEX*16	Implemented
DEFAULTFILE keyword (accepted with warning and ignored)	Obsolete extension
DECODE	Implemented
DISPOSE keyword (accepted with warning and ignored)	Obsolete extension
DO WHILE	Implemented
DOUBLE COMPLEX	Implemented
ENCODE	Implemented
END DO	Implemented

Table 8 —(continued) Fortran 77 language extensions

Extension	Status
FIND	Obsolete extension
IMPLICIT NONE	Implemented
INCLUDE	Implemented
INTEGER*1	Obsolete extension
INTEGER*2	Implemented
INTEGER*4	Implemented
INTEGER*8 (See the section "INTEGER*8" on page 27)	Implemented
IOSTAT keyword	Implemented
LOC	Implemented
LOGICAL*1	Implemented
LOGICAL*2	Implemented
LOGICAL*4	Implemented
LOGICAL*8 (See the section "LOGICAL*8" on page 27)	Implemented
MAXREC keyword (accepted with warning and ignored)	Obsolete extension
NAME keyword	Implemented
NAMELIST	Implemented
NOSPANBLOCKS keyword (accepted with warning and ignored)	Obsolete extension
O edit descriptor	Obsolete extension
PARAMETER (f66/VAX version)	Implemented
POINTER	Implemented
Q edit descriptor	Implemented
R edit descriptor	Obsolete extension
READONLY keyword	Implemented
REAL*4	Implemented
REAL*8	Implemented
REAL*16	Implemented
RECORD type	Implemented
RECORDSIZE keyword (accepted with warning and ignored)	Obsolete extension
RECORDTYPE keyword (accepted with warning and ignored)	Obsolete extension

Table 8 —(continued) Fortran 77 language extensions

Extension	Status
TASK COMMON (See the section "TASK COMMON" on page 27)	Implemented
STATIC	Implemented
TYPE keyword	Implemented
TYPE statement	Implemented
Binary data file format conversions	Obsolete extension
Extended-range DO loops	Implemented
Fortran90 array notation	Implemented
Hex constants	Implemented
Hollerith constants	Implemented
Integers in logical expressions	Obsolete extension
List-directed sequential internal I/O	Implemented
Namelist-directed sequential external I/O	Implemented
Octal constants	Implemented
User-defined conversions	Obsolete extension
Z edit descriptor	Obsolete extension

CPSlib information

CPSlib is the Compiler Parallel Support library—a library of low-level parallelization and synchronization routines. In the SPP1000-Series compilers (/usr/convex/bin/cc, /usr/convex/bin/fc), CPSlib is automatically linked in at every optimization level. However, in the Exemplar compilers, CPSlib is automatically linked in only at +O3 (and above) when +Oparallel is specified.

If your program explicitly calls CPSlib routines or calls other libraries that use CPS routines and you are not compiling at +O3 (or +O4) with +Oparallel, you must explicitly link in CPSlib as shown in the following example.

Assume prog.c contains calls to CPSlib routines:

```
% c89 -lpthread -lcps -lpthread -lail prog.c
```

Linking in CPSlib requires specifying—in the order given—all of the string -lpthread -lcps -lpthread -lail.

See the *Exemplar Programming Guide* for more information on CPSlib routines.

The Exemplar assembler and linker

4

This chapter discusses some of the differences between the Exemplar versions of the assembler (`as`) and the linker (`ld`) and the standard HP-UX versions on which they are based. Also, this chapter presents some examples of using the assembler and the linker. See the following for more information:

- *Assembly Language Reference Manual* (assembler information)
- *Programming on HP-UX* (linker information)
- as(1) and ld(1) man pages

The assembler

An assembler is a program that converts assembly language programs into an object file suitable for processing by the linker `ld`.

The Exemplar assembler `as` differs from the HP-UX `as` in only one way: it supports the `.parallel` directive. This directive sets the parallel attribute in the header of ESOM object files and is provided so that assembly code that was assembled using `/usr/convex/bin/as` will assemble under the Exemplar assembler.

Assembler usage

Assembler commands have the following form:

```
% as [options] [files]
```

where

options

is zero or more of the allowed assembler options (see the as(1) man page for information on options)

files

is a space-delimited list of zero or more files containing assembly code. If no files are given upon invoking `as`, source text is read from standard input

The first example illustrates how to produce an object file from an assembly-language file named prog.s:

```
% ls
prog.s
% as prog.s
% ls
prog.o      prog.s
```

The object file (prog.o) is now ready to be processed by the linker to produce an executable file:

```
% ld prog.o
% ls
a.out       prog.o      prog.s
```

By default, the executable is named a.out; the `-o` *filename* option to `ld` can be used to specify a different name (*filename*) for the executable.

The linker

A linker is a program that combines separate object files into a single object file or executable program.

The Exemplar linker, `ld`, differs from HP's `ld` in that it:

- Supports kernel threads
- Supports the shared-memory classes of the Exemplar programming model (`block_shared`, `near_shared`, and `far_shared` are the available shared-memory classes)
- Produces both SOM and ESOM files (the standard HP `ld` produces only SOM files)
- Is required for using the CXdb debugger and the CXpa profiler

Some of the options that are specific to the Exemplar linker are:

`+A` *alias=symbol*

This option aliases all occurrences of *alias* to *symbol*. This logically renames *alias* to *symbol*, causing all references of the symbol *alias* to resolve to the object pointed to by *symbol*.

`+tnode` *n*

Set the maximum number of threads allocated on each node to *n*. The maximum number of threads cannot be less than 1. The default for maximum number of threads per node is 16.

See the ld(1) man page for more information on these and other Exemplar linker options.

SOM vs. ESOM

Two kinds of executable files exist on the S-Class and X-Class platforms: Standard Object Module (SOM) and Extended Standard Object Module (ESOM).

The SOM format is the format used for HP-UX executables. The ESOM format runs only on the S-Class and X-Class servers and the SPP1200-Series and SPP1600-Series machines. The ESOM format was derived from the SOM format to support multithreaded processes.

If you link using the Exemplar compiler driver, you will get an ESOM executable. If you use the linker directly without specifying the `+tm` *target* option, the resulting executable will be in the SOM format.

Linking to debug or profile

The Exemplar linker, `ld`, is required if you want to use the CXdb debugger (`cxdb`) or the CXpa profiler (`cxpa`). The linker provides support that is needed by both these development tools.

Debugging information is generated by using the `-g` option to the compiler. Profiling information is generated by using the `+pa` option. See Chapter 5, "Debugging and profiling," for more information on using these tools.

Linker usage

See the ld(1) man page for the form of linker commands.

The first example below shows how to combine multiple object files into a single executable file; the executable file is named a.out by default:

```
% ls
file1.o     file2.o     file3.o
% ld file1.o file2.o file3.o
% ls
a.out     file1.o     file2.o     file3.o
```

The linker can also be accessed from the `c89` or `f77` compiler. In the example below, `c89` compiles main.c to produce the object file main.o. The compiler then passes control to the linker, which combines main.o, sub1.o, and sub2.o to produce an executable file. The file main.o is deleted following a successful link.
Because `-o main` is specified, the executable file is named main.

```
% c89 main.c sub1.o sub2.o -o main
% ls
main     main.c     sub1.o     sub2.o
```

Debugging and profiling 5

This chapter provides an overview of the debugging and performance analysis tools available on Exemplar systems. The programs discussed in this chapter are optional products. If you are unsure whether a product is installed on your system, check with your system manager.

See the following documents for more information on these tools:

- *CXdb Reference*
- *CXdb Quick Reference*
- cxdb(1) man page
- *CXpa Reference*
- cxpa(1) man page
- cxoi(1) man page

Note

Debugging with the `dde` and `xdb` debuggers is not supported with code compiled using the Exemplar compilers.

The CXdb debugger

CXdb is a window-based, symbolic debugger that lets you debug Fortran, C, and C++ programs compiled with the Exemplar Fortran (`f77`), C (`cc`, `c89`), and C++ (`CC`) compilers on Exemplar systems.

To debug using CXdb, you must:

- Compile your code using the `-g` option to produce debugging information in the executable file for CXdb to read
- Link the application with the Exemplar linker (`ld`)
- Statically link the application with archived libraries

Note

If `-g` is specified, the Exemplar C and Fortran 77 compilers restrict optimizations to the `+o0` level.

With CXdb, you can:

- Debug an executable file
- Debug a core file
- Obtain a stack backtrace
- Attach to and debug a running process
- Debug at the source code or assembly code level
- Debug MPI applications with multiple processes using a single point of control

CXdb has an X/Motif graphical user interface and a command-line interface for supporting line-oriented terminals.

Using CXdb

To use CXdb in X window mode, follow these steps:

Step 1 Compile (and link using the compiler driver) your program with the `-g` option:

```
% f77 -g prog.f -Wl,-aarchive_shared
```

In this example, the Exemplar linker is automatically used by `f77`. If you do not use the Exemplar linker, you will not be able to use CXdb on the resulting executable. The `-Wl,-aarchive_shared` option links in archive libraries. CXdb does not currently support debugging of shared libraries.

Step 2 Set your `DISPLAY` environment variable (if it is not already set). For example if your display's name is `mydisplay`, in C shell, enter:

```
% setenv DISPLAY mydisplay:0.0
```

Step 3 Invoke CXdb on the executable file:

```
% cxdb a.out &
```

For additional information on using CXdb, refer to the cxdb(1) man page, the CXdb online help system, or the *CXdb Reference*.

The CXpa profiler

CXpa is a performance analysis tool for monitoring program performance at user-selectable source code regions, such as routines, loops, and compiler-generated parallel loops.

Types of performance data you can collect include:

- Wall clock time
- CPU time
- Dynamic call graph
- Iteration/execution counts
- Cache miss counts and latency time for memory accesses

Features of CXpa include the ability to:

- Analyze profiling data in 2D and 3D graphs or text reports
- Clickback to source code during analysis
- View performance data for individual threads or summed across all threads of a process
- Profile MPI and PVM applications

For more information about these events, see the cxpa(1) man page, the CXpa online help system, or the *CXpa Reference*.

Using CXpa

The basic steps in the profiling process are as follows:

1. Prepare the program for profiling, either by compiling with the `+pa` option or instrumenting it with the `cxoi` utility (refer to the cxoi(1) man page for more information).
2. Link using the Exemplar linker (`ld`) by means of the compiler driver.
3. Invoke CXpa (`cxpa`), specifying the name of the executable you want to profile.
4. Select the metrics you want to collect and the source code regions (that is, routines and loops) at which you want them to be collected.
5. Run the program and generate a performance data file (PDF) by

   Running the executable under the control of CXpa

   or

   writing instrumentation selections to the executable file, exiting CXpa, and then running the executable outside CXpa to generate performance data files for later analysis with CXpa.
6. Analyze the results in graphics and reports.

Note

The `+pa` option is not compatible with -p or -G options or with the `+O4` or `+Oall` optimization levels.

System utilities 6

This chapter describes the `mpa` and `sysinfo` utilities; these utilities allow you to make more effective use of your S-Class and X-Class servers. Table 9 on page 61 lists additional utilities that may be useful but are not covered at length in this chapter. Before discussing any of these utilities, however, we need to discuss *subcomplexes* because some of the utilities (such as `mpa`, `scm`, and `sysinfo`) work with subcomplexes.

Subcomplexes

On Exemplar servers, processes run on subcomplexes, which are collections of processors and global memory. Subcomplexes are highly configurable, and configuration is done using the Subcomplex Manager. For more information on the Subcomplex Manager, refer to the scm(1) man page or the *SPP-UX System Administrator's Guide.*

Subcomplexes allow the system administrator to tailor processors and memory to specific application needs, making the most efficient use of system resources. For example, a nonparallel or nontime-critical application can be allocated a single processor; an application containing a lot of fine-grain parallelism can be allocated many processors; and an application requiring large amounts of memory can be allocated processors on several hypernodes. (A hypernode is a set of processors and physical memory organized as a symmetric multiprocessor, or SMP, running a single image of the operating system microkernel.)

Physical configuration

Subcomplexes can consist of from one processor to the total number installed on the server. Hypernodes can be split among as many subcomplexes as there are processors in the hypernode, and subcomplexes can be subsets or supersets of hypernodes.

Processors can only belong to one subcomplex at a time, and every processor must belong to a subcomplex.

Figure 1 shows a 4-hypernode, 64-processor server split into four subcomplexes.

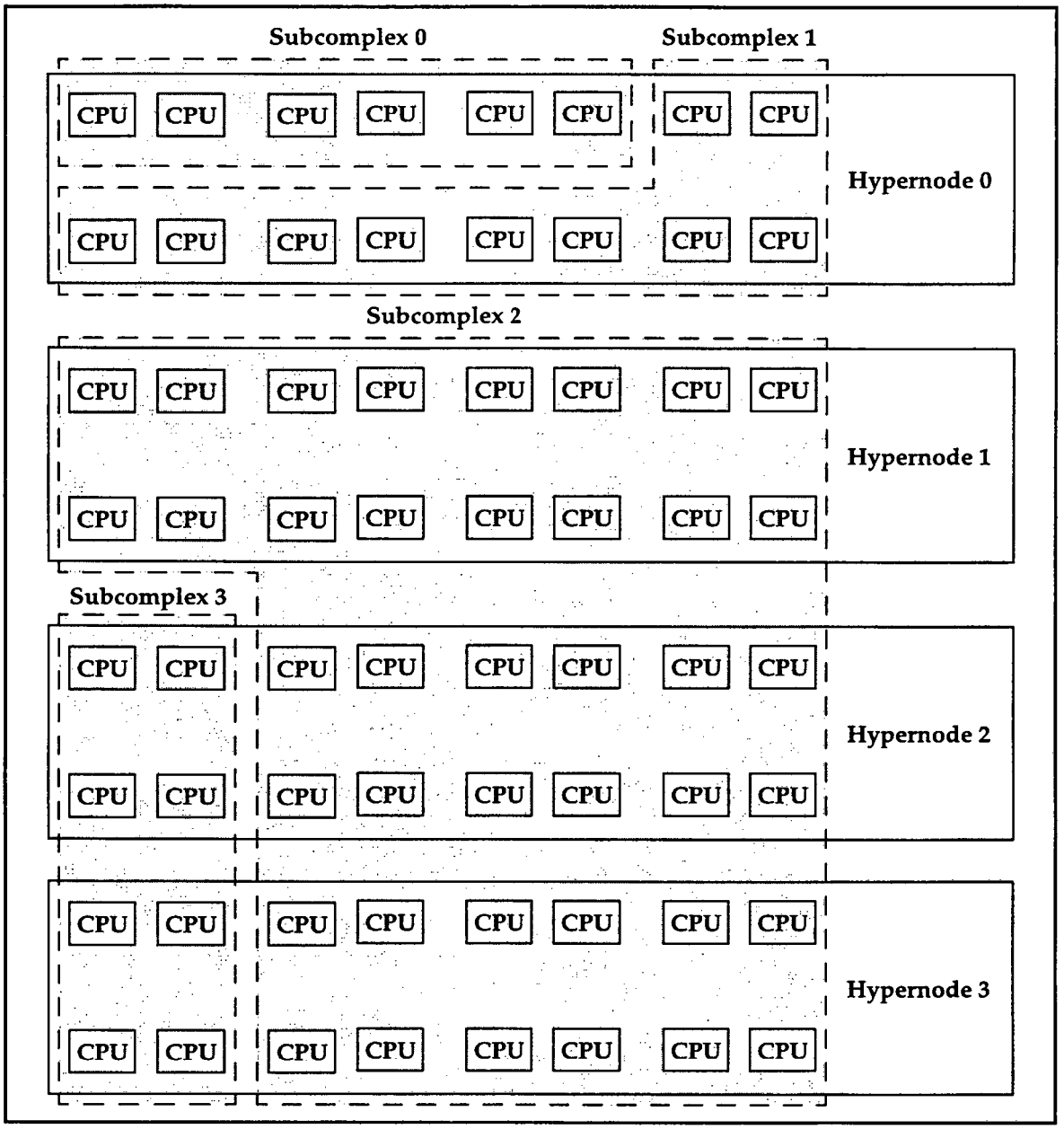

Figure 1 Hypothetical subcomplex configurations

See the *Exemplar Programming Guide* for more information on subcomplexes.

Using the mpa utility

The mpa utility is used to modify program attributes of an executable file. It can control the:

- Subcomplex that an application runs on
- Size of the data segment and the stack size
- Maximum and minimum numbers of threads needed for parallel execution
- Types of memory used for the user stack and thread-specific memory

Examples of using mpa

This section shows several short examples of how to use the mpa utility. The examples assume that the executable a.out was compiled using +O3 +Oparallel or +O4 +Oparallel, and hence is a parallel executable.

Run the program a.out on the subcomplex named chemistry:

```
% mpa -sc chemistry a.out
```

Run the program a.out using at least 8 threads, but not more than 16 threads:

```
% mpa -min 8 -max 16 a.out
```

Run the program a.out, setting the number of threads the executable will demand to four. If four processors are not available, the -over option enables oversubscription (running more than one thread per processor):

```
% mpa -min 4 -max 4 -over a.out
```

Run the program a.out, setting the stack size to the largest size supported by the system (by specifying -STACK in all uppercase without an argument):

```
% mpa -STACK a.out
```

You can set the stack size to sizes less than the largest allowed by the system by using -stack *s*, where *s* is some positive integer.

Getting additional mpa information

For more information on using mpa, see the mpa(1) man page.

Using the `sysinfo` utility

The `sysinfo` command provides system information regarding memory, processors, and subcomplexes. This command can produce information such as:

- Unix server version string
- Basic processor information, including total number of processors
- Load averages for the system, a certain node, or a certain subcomplex
- Amounts of total, allocated, and free memory

Examples of using `sysinfo`

This section provides examples of how to use the `sysinfo` utility.

Display all available system information:

```
% sysinfo -a
```

Display the total number of CPUs in the system:

```
% sysinfo -cpu_count
```

Display the load average for all subcomplexes:

```
% sysinfo -ls
```

Display memory statistics for the entire system:

```
% sysinfo -memc
```

Getting additional `sysinfo` information

For more information on using `sysinfo`, see the sysinfo(1) man page.

Additional utilities

Table 9 lists other system utilities that you may find helpful in using your S-Class or X-Class technical server. Sources for additional information on these utilities are given in the second column of the table.

Table 9 Additional system utilities

`file`	Determines file types. If a file is in the ESOM format, the command output explicitly states this fact. Similarly, if a file is parallel, the command output explicitly states this fact. See the file(1) man page for more information.
`make`	Maintains, updates, and regenerates groups of programs.
`mnm`	Monitors total memory usage per hypernode; use `-h` to get a listing of options.
`nm`	Prints the name list of an object file or library; `nm` is useful to see where symbols are defined and referenced. See the nm(1) man page for more information.
`pot`	The `pot` utility is similar to the `top` utility but is thread-based rather than process-based. (`top` displays information about the top processes—in terms of CPU usage—on a system.) `pot` can display various information; the particular information displayed and the order in which it is displayed can be configured by the user. Use `top` for gathering data on serial processes and `pot` for data on serial/parallel processes. See the pot(1) man page for more information.
`scm`	Subcomplex Manager: shows configuration of processors and memory resources. See the scm(1) man page for more information.
`size`	Prints section sizes of object files—text, data, bss (uninitialized data), and the total size. This information is helpful in determining if your program is within the tunables limits. (Tunables are specified in the file /stand/tunables.) See the size(1) man page for more information.
`sod`	Displays standard format object files in a human-readable form; using the `-a` option displays all of the auxiliary headers—these headers contain information about the minimum and maximum CPUs and the memory types. See the sod(1) man page for more information.
`syspic`	Monitors system performance. See the syspic(1) man page for more information.
`top`	Displays and updates information about the top processes on the system (processes are ranked by raw CPU percentage). Use `top` for gathering data on serial processes and `pot` for data on serial/parallel processes. See the top(1) man page for more information.

Environment variables

A

The Exemplar compilers recognize many of the environment variables accepted by the standard HP `c89` and `f77` compilers. This chapter describes some of those environment variables. See the following documents for more information on environment variables:

- c89(1) man page
- f77(1) man page
- *HP C/HP-UX Programmer's Guide*
- *HP C/HP-UX Reference Manual*
- *HP FORTRAN/9000 Programmer's Guide*
- *HP FORTRAN/9000 Programmer's Reference*

The following environment variables are discussed in this appendix:

- `CCOPTS`
- `FCOPTS`
- `MP_NUMBER_OF_THREADS`
- `TMPDIR`

Note

The `MP_NUMBER_OF_THREADS` environment variable is the only environment variable starting with `MP_` that is accepted by the Exemplar compilers using either `+Okernel_threads` or `+Oprocess_threads`. Other environment variables starting with `MP_` are accepted only if +Oprocess_threads is specified.

CCOPTS

You can specify c89 compiler options by using the CCOPTS environment variable or by including them on the command line. The CCOPTS environment variable provides a convenient way for establishing default options for the c89 command line.

The syntax for setting the CCOPTS environment variable (in C shell notation) is:

```
% setenv CCOPTS [options] [ | [options]]
```

where

options

is a space-delimited string of one or more compiler options

If you specify more than one option or you use the pipe (|), enclose the entire string in quotes.

The compiler places the options that appear before the pipe in front of the command-line options to c89. It then places the second group of options after any command-line options to c89.

Options that appear after the pipe in the CCOPTS variable override and take precedence over options supplied on the c89 command line.

If the pipe is omitted, the compiler gets the value of CCOPTS and places its contents before any options on the command line.

For example, the following (in C shell notation)

```
% setenv CCOPTS -v
% c89 -g prog.c
```

is equivalent to

```
% c89 -v -g prog.c
```

Using the pipe, the following (in C shell notation)

```
% setenv CCOPTS "-v | +O1"
% c89 +O2 prog.c
```

is equivalent to

```
% c89 -v +O2 prog.c +O1
```

In the above example, level 1 optimization is performed because the +O1 option appearing after the pipe in CCOPTS takes precedence over the c89 command-line options.

FCOPTS

You can specify `f77` compiler options by using the `FCOPTS` environment variable or by including them on the command line. The `FCOPTS` environment variable provides a convenient way for establishing default options for the `f77` command line.

The syntax for setting the `FCOPTS` environment variable (in C shell notation) is:

```
% setenv FCOPTS [options] [ | [options]]
```

where

options

is a space-delimited string of one or more compiler options

If you specify more than one option or you use the pipe (|), enclose the entire string in quotes.

The compiler places the options that appear before the pipe in front of the command-line options to `f77`. It then places the second group of options after any command-line options to `f77`.

Options that appear after the pipe in the `FCOPTS` variable override and take precedence over options supplied on the `f77` command line.

If the pipe is omitted, the compiler gets the value of `FCOPTS` and places its contents before any options on the command line.

For example, the following (in C shell notation)

```
% setenv FCOPTS -v
% f77 -L prog.f
```

is equivalent to

```
% f77 -v -L prog.f
```

Using the pipe, the following (in C shell notation)

```
% setenv FCOPTS "-O | -lmylib"
% f77 -v prog.f
```

is equivalent to

```
% f77 -O -v prog.f -lmylib
```

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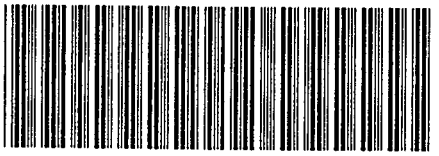

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