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Welcome to Intel® Fortran Compiler

The Intel® Fortran Compiler version 7.1 compiles code targeted for the IA-32 Intel® architecture and Intel® Itanium® architecture. The Intel Fortran Compiler has a variety of options that enable you to use the compiler features for higher performance of your application.

In addition to the Getting Started with the Intel® Fortran Compiler section included with this document, for installing and more details on getting started, see Intel® Fortran Compiler Installing and Getting Started document.

Major Components of the Intel® Fortran Compiler Product

Intel® Fortran Compiler product includes the following components for the development environment:

- Intel® Fortran Compiler for 32-bit Applications
- Intel® Fortran Itanium® Compiler for Itanium-based Applications
- Intel Debugger (IDB)

The Intel Fortran Compiler for Itanium-based applications includes Intel® Itanium® Assembler and Intel Itanium® Linker. This documentation assumes that you are familiar with the Fortran programming language and with the Intel® processor architecture. You should also be familiar with the host computer's operating system.

What's New in This Release

This document combines information about Intel® Fortran Compiler for IA-32-based applications and Itanium®-based applications. IA-32-based applications correspond to the applications run on any processor of the Intel® Pentium® processor family generations, including the Intel® Xeon(TM) processor and Intel® Pentium® M Processor. Itanium-based applications correspond to the applications run on the Intel® Itanium® and Itanium 2 processors.

The following variations of the compiler are provided for you to use according to your host system's processor architecture and targeted architectures.

- Intel® Fortran Compiler for 32-bit Applications is designed for IA-32 systems, and its command is ifc. The IA-32 compilations run on any IA-32 Intel processor and produce applications that run on IA-32 systems. This compiler can be optimized specifically for one or more Intel IA-32 processors, from Intel® Pentium® to Pentium 4 to Celeron(TM) and Intel® Xeon(TM) processors.
Intel® Fortran Itanium® Compiler for Itanium®-based Applications (native compiler) is designed for Itanium architecture systems, and its command is `efc`. This compiler runs on Itanium-based systems and produces Itanium-based applications. Itanium-based compilations can only operate on Itanium-based systems.

**Improvements and New Features in 7.1**

- New Intel® Pentium® M processor support with `-axW` and `-xW` options.
- Support of Cray* pointers within the Fortran modules
- New options: `-complex_limited_range` and `-[no]stack_temps`

**Improvements and New Features in 7.0**

- New Intel® Itanium® and Itanium 2 processors support with `-tppl` and `-tpp2` options
- New OpenMP* option, `-openmp_stubs`
- Support of `.mod` files for parallel invocations and the `-module` option
- Extended optimization directives

The Intel Fortran Compiler has a variety of options that enable you to use the compiler features for higher performance of your application. For new options in this release, see [New Compiler Options](#).

⚠️ Note

Please refer to the Release Notes for the most current information about features implemented in this release.

**Hyper-Threading Technology Support**

Both auto-parallelization and OpenMP features support Hyper-Threading Technology. Hyper-Threading Technology enables the operation of multiple logical processors to share execution resources in each physical processor package. It increases system throughput when executing multithreaded applications or when multitasked workloads are running concurrently.

**OpenMP* Support**

The Intel® Fortran Compiler supports OpenMP API version 2.0 and performs code transformation for shared memory parallel programming. The OpenMP support is accomplished with the `-openmp` option. In addition, the functionality of the OpenMP has been reinforced with new option,
-openmp_stubs.

Optimizing for Intel® Itanium® 2 Processor Family

New options -tpp1 and -tpp2 provide specific support for Intel® Itanium® and Itanium 2 processors.

Support of Parallel Invocations

The programs in which modules are defined support valuable compilation mechanisms, such as parallel invocations with make file for Inter-procedural optimizations of multiple files and of the whole program. In addition, the programs that require modules located in multiple directories, can be compiled using the -I<dir> option to locate the .mod files (modules) that should be included in the program. The new -module option specifies the directory to route the module files.

Extended Optimization Directives

In addition to the compiler options, Intel Fortran Compiler supports Intel-extended language directives perform various tasks during compilation to enhance optimization of application code. A few directives for software pipelining, loop unrolling and prefetching have been added.

Features and Benefits

The Intel® Fortran Compiler enables your software to perform the best on Intel architecture-based computers. Using new compiler optimizations, such as the whole-program optimization and profile-guided optimization, prefetch instruction and support for Streaming SIMD Extensions (SSE) and Streaming SIMD Extensions 2 (SSE2), the Intel Fortran Compiler provides high performance.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Performance</td>
<td>Achieve a significant performance gain by using optimizations</td>
</tr>
<tr>
<td>Support for Streaming SIMD Extensions</td>
<td>Advantage of new Intel microarchitecture</td>
</tr>
<tr>
<td>Automatic vectorizer</td>
<td>Advantage of parallelism in your code achieved automatically</td>
</tr>
<tr>
<td>Parallelization</td>
<td>Automatic generation of multithreaded code for loops. Shared memory parallel programming with OpenMP*</td>
</tr>
<tr>
<td>Floating-point optimizations</td>
<td>Improved floating-point performance</td>
</tr>
<tr>
<td>Data prefetching</td>
<td>Improved performance due to the accelerated data delivery</td>
</tr>
<tr>
<td>Interprocedural optimizations</td>
<td>Larger application source files perform better</td>
</tr>
</tbody>
</table>
Product Web Site and Support

For the latest information about Intel Fortran Compiler, visit the Intel® Fortran Compiler home page where you can find:

- Fortran compiler performance-related information
- Marketing information
- Internet-based support and resources
- Intel Architecture Performance Training Center


For specific details on the Itanium® architecture, visit the web site at http://developer.intel.com/design/itanium/index.htm?iid=search+Itanium&.

System Requirements

The Intel® Fortran Compiler can be run on personal computers that are based on Intel® architecture processors. To compile programs with this compiler, you need to meet the processor and operating system requirements.

Minimum Hardware Requirements

IA-32 Compiler

- A system based on an Intel® Pentium®, Intel® Xeon(TM) processor or subsequent IA-32 processor.
- 128 MB RAM
- 100 MB disk space

Recommended: A system with Pentium 4 or Intel Xeon processor and 256 MB of RAM.
Itanium® Compiler

- Itanium-processor-based system. The Itanium®-based systems are shipped with all of the hardware necessary to support this Itanium® compiler.

- 512 MB RAM (1GB RAM recommended)

- 100 MB disk space

Operating System Requirements

IA-32 architecture:
For the current Linux* versions of kernel and glibc supported, please refer to the product Release Notes.

Itanium® architecture:
To run Itanium®-based applications, you must have an Intel® Itanium® architecture system running the Itanium®-based operating system. Itanium®-based systems are shipped with all of the hardware necessary to support this product. For the current Linux versions of kernel and glibc supported, please refer to the product Release Notes.

It is the responsibility of application developers to ensure that the operating system and processor on which the application is to run support the machine instructions contained in the application.

For use/call-sequence of the libraries, see the library documentation provided in your operating system. For GNU libraries for Fortran, refer to http://www.gnu.org/directory/gcc.html in case they are not installed with your operating system.

Browser

For both architectures, the browser Netscape*, version 4.74 or higher is required.

FLEXlm* Electronic Licensing

The Intel® Fortran Compiler uses the GlobeTrotter* FLEXlm* licensing technology. The compiler requires valid license file in the licenses directory in the installation path. The default directory is /opt/intel/licenses and the license files have a file extension of .lic.

Using the Intel® License Manager for FLEXlm* describes how to install and use the Intel® License Manager for FLEXlm to configure a license server for systems using counted licenses.
How to Use This Document

This User's Guide explains how you can use the Intel® Fortran Compiler. It provides information on how to get started with the Intel Fortran Compiler, how this compiler operates and what capabilities it offers for high performance. You will learn how to use the standard and advanced compiler optimizations to gain maximum performance of your application.

This documentation assumes that you are familiar with the Fortran Standard programming language and with the Intel® processor architecture. You should also be familiar with the host computer's operating system.

✍️ Note:
This document explains how information and instructions apply differently to each targeted architecture. If there is no specific indication to either architecture, the description is applicable for both architectures.

Notation Conventions

This documentation uses the following conventions:

<table>
<thead>
<tr>
<th>This type style</th>
<th>An element of syntax, a reserved word, a keyword, a file name, or a code example. The text appears in lowercase unless uppercase is required.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>This type style</strong></td>
<td>Indicates the exact characters you type as input.</td>
</tr>
<tr>
<td><strong>This type style</strong></td>
<td>Indicates command line arguments and option arguments you enter.</td>
</tr>
<tr>
<td><strong>This type style</strong></td>
<td>Indicates an argument on a command line or an option’s argument in the text.</td>
</tr>
<tr>
<td>[options]</td>
<td>Indicates that the items enclosed in brackets are optional.</td>
</tr>
<tr>
<td>{value</td>
<td>value}</td>
</tr>
<tr>
<td>... (ellipses)</td>
<td>Ellipses in the code examples indicate that part of the code is not shown.</td>
</tr>
<tr>
<td><strong>This type style</strong></td>
<td>Indicates an Intel Fortran Language extension code example.</td>
</tr>
<tr>
<td><strong>This type style</strong></td>
<td>Indicates an Intel Fortran Language extension discussion. Throughout the manual, extensions to the ANSI standard Fortran language appear in this color to help you easily identify when your code uses a non-standard language extension.</td>
</tr>
<tr>
<td><strong>This type style</strong></td>
<td>Hypertext</td>
</tr>
</tbody>
</table>

Related Publications
The following documents provide additional information relevant to the Intel Fortran Compiler:


Information about the target architecture is available from Intel and from most technical bookstores. Most Intel documents are available from the Intel Corporation web site at [www.intel.com](http://www.intel.com). Some helpful titles are:

- *Intel® Fortran Libraries Reference*, doc. number 687929
- *Intel® Fortran Programmer's Reference*, doc. number 687928
- *Using the Intel® License Manager for FLEXlm* 
- VTune(TM) Performance Analyzer online help
- *Intel Architecture Software Developer's Manual*
  - Vol. 1: Basic Architecture, Intel Corporation, doc. number 243190
  - Vol. 3: System Programming, Intel Corporation, doc. number 243192
- *Intel® Itanium® Architecture Application Developer's Architecture Guide*
- *Intel® Itanium® Architecture Software Developer's Manual*
  - Vol. 1: Application Architecture, Intel Corporation, doc. number 245317
  - Vol. 2: System Architecture, Intel Corporation, doc. number 245318
  - Vol. 3: Instruction Set Reference, Intel Corporation, doc. number 245319
- *Intel® Itanium® Architecture Software Conventions & Runtime Architecture Guide*
- *Intel® Itanium® Architecture Assembly Language Reference Guide*
- *Intel® Itanium® Assembler User's Guide*
• *Pentium® Processor Family Developer's Manual*

• *Intel® Processor Identification with the CPUID Instruction*, Intel Corporation, doc. number 241618

For developer’s manuals on Intel processors, refer to the [Intel's Literature Center](http://www.intel.com).  

### Publications on Compiler Optimizations

The following sources are useful in helping you understand basic optimization and vectorization terminology and technology:

• *Intel® Architecture Optimization Reference Manual*


• *Efficient Exploitation of Parallelism on Pentium® III and Pentium® 4 Processor-Based Systems*, Aart Bik, Milind Girkar, Paul Grey, and Xinmin Tian.
Options Quick Reference Guides

This section provides three sets of tables comprising Intel® Fortran Compiler Options Quick Reference Guides:

- Alphabetical Listing, alphabetic tabular reference of all compiler and compilation as well as linker and linking control, and all other options implemented by the Intel Fortran Compiler available for both IA-32 and Intel® Itanium® compilers as well as those available exclusively for each architecture.

- Summary tables for IA-32 and Itanium compiler features with the options that enable them

- Compiler Options for Windows* and Linux* Cross-reference

Conventions used in the Options Quick Guide Tables

| [-] | indicates that option is ON by default, and if option includes "-", the option is disabled; for example, \(-cerrs\) disables printing errors in a terse format. |
| [n] | indicates that the value in [ ] can be omitted or have various values; for example, in \(-unroll\[n\] \) option, \(n\) can be omitted or have different values starting from 0. |
| Values in {} with vertical bars | are used for option's version; for example, option \(-i\{2 \mid 4 \mid 8\}\) has these versions: \(-i2\), \(-i4\), \(-i8\). |
| {n} | indicates that option must include one of the fixed values for \(n\); for example, in option \(-Zp\{n\}\), \(n\) can be equal to 1, 2, 4, 8, 16. |
| Words in this style following an option | indicate option's required argument(s). Arguments are separated by comma if more than one are required. For example, the option \(-Qoption, tool, opts\) looks in the command line like this: \(prompt>ifc -Qoption, link, -w myprog.f\) |

New Compiler Options

The following table lists new options in this release. See Conventions Used in the Options Quick Guide Tables.

- Options specific to the Itanium® architecture (Itanium®-based systems only)

All other options are available for both IA-32 and Itanium architectures.
<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-complex_limited_range[-]</code></td>
<td>Enables or disables (default) the use of the basic algebraic expansions of some complex arithmetic operations. This can enable some performance improvement in programs which use a lot of complex arithmetic operations at the loss of some exponent range.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-dynamic-linker (file)</code></td>
<td>Specifies in <code>file</code> a dynamic linker of choice, rather than default.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-module[path] -nomodule</code></td>
<td>Specifies the directory where the module files (extension <code>.mod</code>) are placed. Omitting this option or specifying <code>-nomodule</code> results in placing the <code>.mod</code> files in the directory where the source files are being compiled.</td>
<td><code>-nomodule</code></td>
</tr>
<tr>
<td><code>-[no]stack_temps</code></td>
<td>Allocates temporary array in the heap (default) or on the runtime stack with <code>-stack_temps</code>.</td>
<td><code>-nostack_temps</code></td>
</tr>
<tr>
<td>`-Ob{0</td>
<td>1</td>
<td>2}`</td>
</tr>
<tr>
<td></td>
<td>-<code>Ob0</code>: disable inlining</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-<code>Ob1</code>: disables inlining unless <code>-ip</code> or <code>-Ob2</code> is specified. Enables inlining of functions.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-<code>Ob2</code>: Enables inlining of any function. However, the compiler decides which functions are inlined. This option enables interprocedural optimizations and has the same effect as specifying the <code>-ip</code> option.</td>
<td></td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-openmp_stubs</td>
<td>Enables to compile OpenMP programs in sequential mode. The OpenMP directives are ignored and a stub OpenMP library is linked (sequentially).</td>
<td>OFF</td>
</tr>
<tr>
<td>-safe_cray_ptr</td>
<td>Specifies that Cray pointers do not alias with other variables.</td>
<td>OFF</td>
</tr>
<tr>
<td>-list</td>
<td>Prints a source listing on stdout.</td>
<td>OFF</td>
</tr>
<tr>
<td>-list -showinclude</td>
<td>Prints a source listing to stdout with contents of INCLUDE files.</td>
<td>OFF</td>
</tr>
<tr>
<td>-tppl Itanium®-based systems</td>
<td>Targets optimization to the Intel® Itanium® processor for best performance.</td>
<td>OFF</td>
</tr>
<tr>
<td>-tpp2 Itanium-based systems</td>
<td>Targets optimization to the Intel® Itanium® 2 processor for best performance. Generated code is compatible with the Itanium processor.</td>
<td>ON</td>
</tr>
</tbody>
</table>

Compiler Options Quick Reference Alphabetical

The following table describes options that you can use for compilations you target to either IA-32- or Itanium®-based applications or both. See Conventions Used in the Options Quick Guide Tables.

- Options specific to IA-32 architecture (IA-32 only)
- Options specific to the Itanium® architecture (Itanium-based systems only)

All other options are available for both IA-32 and Itanium architectures.

-0f_check IA-32 compiler
  Enables a software patch for Pentium® processor 0f erratum.
  More...
<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>Executes any DO loop at least once. Same as -onetrip.</td>
<td>OFF</td>
</tr>
<tr>
<td>-72, -80, -132</td>
<td>Specifies 72, 80 or 132 column lines for fixed form source only. The compiler might issue a warning for non-numeric text beyond 72 for the -72 option.</td>
<td>-72</td>
</tr>
<tr>
<td>-align</td>
<td>Analyzes and reorders memory layout for variables and arrays.</td>
<td>ON</td>
</tr>
<tr>
<td>-ansi_alias[-]</td>
<td>Enables (default) or disables assumption of the programs ANSI conformance.</td>
<td>ON</td>
</tr>
<tr>
<td>-auto</td>
<td>Makes all local variables AUTOMATIC.</td>
<td>OFF</td>
</tr>
<tr>
<td>-autodouble</td>
<td>Sets the default size of real numbers to 8 bytes; same as -r8.</td>
<td>OFF</td>
</tr>
<tr>
<td>-auto_scalar</td>
<td>Makes scalar local variables AUTOMATIC.</td>
<td>ON</td>
</tr>
<tr>
<td>-ax{i</td>
<td>M</td>
<td>K</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Status</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>-Bdynamic</td>
<td>Used with <code>-lname</code> (see in this table), enables dynamic linking of libraries at run time. Compared to static linking, results in smaller executables.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Bstatic</td>
<td>Enables linking a user's library statically.</td>
<td>OFF</td>
</tr>
<tr>
<td>-c</td>
<td>Stops the compilation process after an object file (.o) has been generated.</td>
<td>OFF</td>
</tr>
<tr>
<td>-C90</td>
<td>Links with an alternative I/O library (<code>libCEPCF90.a</code>) that supports mixed input and output with C on the standard streams.</td>
<td>OFF</td>
</tr>
<tr>
<td>-C</td>
<td>Equivalent to: (<code>-CA</code>, <code>-CB</code>, <code>-CS</code>, <code>-CU</code>, <code>-CV</code>) extensive runtime diagnostics options.</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>IA-32 compiler</td>
<td>OFF</td>
</tr>
<tr>
<td>-CA</td>
<td>Generates runtime code, which checks whether pointers and allocatable array references are defined and allocated. Should be used in conjunction with <code>-d{n}</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>IA-32 compiler</td>
<td>OFF</td>
</tr>
<tr>
<td>-CB</td>
<td>Generates runtime code to check that array subscript and substring references are within declared bounds. Should be used in conjunction with <code>-d{n}</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>IA-32 compiler</td>
<td>OFF</td>
</tr>
<tr>
<td>-CS</td>
<td>Generates runtime code that checks for consistent shape of intrinsic procedure. Should be used in conjunction with <code>-d{n}</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-CU</td>
<td>Generates runtime code that causes a runtime error if variables are used without being initialized. Should be used in conjunction with -d {n}.</td>
<td>OFF</td>
</tr>
<tr>
<td>-CV</td>
<td>On entry to a subprogram, tests the correspondence between the actual arguments passed and the dummy arguments expected. Both calling and called code must be compiled with -CV for the checks to be effective. Should be used in conjunction with -d {n}.</td>
<td>OFF</td>
</tr>
<tr>
<td>-cerrs[-]</td>
<td>Enables/disables errors and warning messages to be printed in a terse format for diagnostic messages.</td>
<td>OFF</td>
</tr>
<tr>
<td>-cm</td>
<td>Suppresses all comment messages.</td>
<td>OFF</td>
</tr>
<tr>
<td>-common_args</td>
<td>Assumes by reference subprogram arguments may alias one another.</td>
<td>OFF</td>
</tr>
<tr>
<td>-complex_limited_range[-]</td>
<td>Enables or disables (default) the use of the basic algebraic expansions of some complex arithmetic operations. This can enable some performance improvement in programs which use a lot of complex arithmetic operations at the loss of some exponent range.</td>
<td>OFF</td>
</tr>
<tr>
<td>-cpp{n}</td>
<td>Same as -fpp{n}.</td>
<td>OFF</td>
</tr>
<tr>
<td>-DD</td>
<td>Compiles debugging statements indicated by the letter D in column 1 of the source code.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-DX</td>
<td>Compiles debugging statements indicated by the letters X in column 1 of the source code.</td>
<td>OFF</td>
</tr>
<tr>
<td>-DY</td>
<td>Compiles debugging statements indicated by the letters Y in column 1 of the source code.</td>
<td>OFF</td>
</tr>
<tr>
<td>-d{n}</td>
<td>Sets diagnostics level as follows:</td>
<td>-d0</td>
</tr>
</tbody>
</table>
| IA-32 compiler | -d0 - displays proclname line  
|             | -d1 - displays local scalar variables  
|             | -d2 - local and common scalars  
<p>|             | -d&gt;2 - display first n elements of local and COMMON arrays, and all scalars. |         |
| -Dname[=text]| Defines a macro name and associates it with the specified value.            | OFF     |
| -dps, -nodps| Enable (default) or disable DEC* parameter statement recognition.           | -dps    |
| -dryrun     | Show driver tool commands but do not execute tools.                         | OFF     |
| -dynamic-linker(file)| Specifies in file a dynamic linker of choice, rather than default.          | OFF     |
| -e90, -e95 | Enable issuing of errors rather than warnings for features that are non-standard Fortran. | OFF     |</p>
<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>-E</td>
<td>Preprocesses the source files and writes the results to stdout. If the file name ends with capital F, the option is treated as -fpp1.</td>
<td>OFF</td>
</tr>
<tr>
<td>-EP</td>
<td>Preprocesses the source files and writes the results to stdout omitting the #line directives.</td>
<td>OFF</td>
</tr>
<tr>
<td>-extend_source</td>
<td>Enables extended (132-character) source lines. Same as -132.</td>
<td>OFF</td>
</tr>
<tr>
<td>-F</td>
<td>Preprocesses the source files and writes the results to file.</td>
<td>OFF</td>
</tr>
<tr>
<td>-falias</td>
<td>Assumes aliasing in program.</td>
<td>ON</td>
</tr>
<tr>
<td>-fno-alias</td>
<td>Assumes no aliasing in program.</td>
<td>OFF</td>
</tr>
<tr>
<td>-ffnalias</td>
<td>Assumes aliasing within functions.</td>
<td>ON</td>
</tr>
<tr>
<td>-fno-fnalias</td>
<td>Assumes no aliasing within functions, but assumes aliasing across calls.</td>
<td>OFF</td>
</tr>
<tr>
<td>-fcode_asm</td>
<td>Inserts code byte annotations in assembly file produced with -S.</td>
<td>OFF</td>
</tr>
<tr>
<td>-fsource_asm</td>
<td>Inserts high-level source code annotations in assembly file produced with -S.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-fverbose-asm</td>
<td>Inserts in an assembly file compiler comments including compiler version and options. Enabled by default when producing an assembly file (with <code>-S</code>).</td>
<td>OFF</td>
</tr>
<tr>
<td>-fnoverbose-asm</td>
<td>Disables <code>-fverbose-asm</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td>-FI</td>
<td>Specifies that the source code is in fixed format. This is the default for source files with the file extensions <code>.for</code>, <code>.f</code>, or <code>.ftn</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td>-fnsplit-</td>
<td>Disables function splitting, which is enabled by <code>-prof_use</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>Itanium compiler</td>
<td></td>
</tr>
<tr>
<td>-fp</td>
<td>Disables the use of the <code>ebp</code> register in optimizations. Directs to use the <code>ebp</code>-based stack frame for all functions.</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>IA-32 compiler</td>
<td></td>
</tr>
<tr>
<td>-fpp{n}</td>
<td>Enables the Fortran preprocessor (<code>fpp</code>) on all Fortran source files prior to compilation. <code>n=0</code>: disable CVF and <code>#</code> directives. <code>n=1</code>: enable CVF conditional compilation and <code>#</code> directives; when <code>fpp</code> runs, <code>-fpp1</code> is the default. <code>n=2</code>: enable only <code>#</code> directives, <code>n=3</code>: enable only CVF conditional compilation directives.</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-fp_port</td>
<td>Rounds floating-point results at assignments and casts. Some speed impact.</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>IA-32 compiler</td>
<td></td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Status</td>
</tr>
<tr>
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</tr>
<tr>
<td>-FR</td>
<td>Specifies that the source code is in Fortran free format. This is the default for source files with the .f90 file extension.</td>
<td>OFF</td>
</tr>
<tr>
<td>-ftz[-]</td>
<td>Flushed denormal results to zero. Turned on by -O3.</td>
<td>OFF</td>
</tr>
<tr>
<td>-g</td>
<td>Generates symbolic debugging information and line numbers in the object code for use by source-level debuggers.</td>
<td>OFF</td>
</tr>
<tr>
<td>-help</td>
<td>Prints help message.</td>
<td>OFF</td>
</tr>
<tr>
<td>-i{2</td>
<td>4</td>
<td>8}</td>
</tr>
<tr>
<td>-I*dir</td>
<td>Specifies an additional directory to search for include files whose names do not begin with a slash (/).</td>
<td>OFF</td>
</tr>
<tr>
<td>-i_dynamic</td>
<td>Sets dynamic linking of Intel-provided libraries as default.</td>
<td>OFF</td>
</tr>
<tr>
<td>-implicitnone</td>
<td>Sets IMPLICIT NONE as the default. Same as -u.</td>
<td>OFF</td>
</tr>
<tr>
<td>-inline_debug_info</td>
<td>Keep the source position of inlined code instead of assigning the call-site source position to inlined code.</td>
<td>OFF</td>
</tr>
<tr>
<td>-ip</td>
<td>Enables single-file interprocedural optimizations.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>State</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>-ip_no_inlining</td>
<td>Disables full or partial inlining that would result from the -ip interprocedural optimizations. Requires -ip or -ipo.</td>
<td>ON</td>
</tr>
<tr>
<td>-ip_no_pinlining</td>
<td>Disables partial inlining. Requires -ip or -ipo.</td>
<td>OFF</td>
</tr>
<tr>
<td>-IPF_fma[-]</td>
<td>Enables/disables the contraction of floating-point multiply and add/ subtract operations into a single operation.</td>
<td>ON</td>
</tr>
<tr>
<td>-IPF_fp_speculation</td>
<td>Sets the compiler to speculate on floating-point (fp) operations in one of the following modes: fast: speculate on fp operations; safe: speculate on fp operations only when it is safe; strict: enables the compiler’s speculation on floating-point operations preserving floating-point status in all situations; same as off in the current version. off: disables the fp speculation.</td>
<td>fast</td>
</tr>
<tr>
<td>-IPF_flt_eval_method0</td>
<td>- IPF_flt_eval_method0 directs the compiler to evaluate the expressions involving floating-point operands in the precision indicated by the program.</td>
<td>OFF</td>
</tr>
<tr>
<td>-IPF_fltacc[-]</td>
<td>- IPF_fltacc disables optimizations that affect floating-point accuracy. The default is to enable such optimizations.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Status</td>
</tr>
<tr>
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<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>-ipo</td>
<td>Enables interprocedural optimization across files. Compile all objects over entire program with multifile interprocedural optimizations.</td>
<td>OFF</td>
</tr>
<tr>
<td>-ipo_c</td>
<td>Optimizes across files and produces a multifile object file. This option performs optimizations as -ipo, but stops prior to the final link stage, leaving an optimized object file.</td>
<td>OFF</td>
</tr>
<tr>
<td>-ipo_obj</td>
<td>Forces the generation of real object files. Requires -ipo.</td>
<td>IA-32: OFF</td>
</tr>
<tr>
<td>-ipo_S</td>
<td>Optimizes across files and produces a multifile assembly file. This option performs optimizations as -ipo, but stops prior to the final link stage, leaving an optimized assembly file.</td>
<td>OFF</td>
</tr>
<tr>
<td>-ivdep_parallel</td>
<td>Indicates there is absolutely no loop-carried memory dependency in the loop where IVDEP directive is specified.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Kpic, -KPIC</td>
<td>Generates position-independent code.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Ldir</td>
<td>Instructs linker to search dir for libraries.</td>
<td>OFF</td>
</tr>
<tr>
<td>-lname</td>
<td>Links with a library indicated in name.</td>
<td>OFF</td>
</tr>
<tr>
<td>-list</td>
<td>Prints a source listing to stdout (typically, your terminal screen) without contents of include files.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-list -showinclude</td>
<td>Prints a source listing to stdout with contents of include files expanded.</td>
<td>OFF</td>
</tr>
<tr>
<td>-lowercase</td>
<td>Sets the case of external linker symbols such as subroutine names to be lowercase characters.</td>
<td>ON</td>
</tr>
<tr>
<td>-module[&lt;path&gt;], -nomodule</td>
<td>Specifies the directory where the module files (extension .mod) are placed. Omitting this option or specifying -nomodule results in placing the .mod files in the directory where the source files are being compiled.</td>
<td>-nomodule</td>
</tr>
<tr>
<td>-mp</td>
<td>Maintains declared floating point precision as well as conformance to the IEEE* 754 standards for floating-point arithmetic. Optimization is reduced accordingly.</td>
<td>OFF</td>
</tr>
<tr>
<td>-mpl</td>
<td>Restricts floating point precision to be closer to declared precision. Some speed impact, but less than –mp.</td>
<td>OFF</td>
</tr>
<tr>
<td>-nbs</td>
<td>Treats backslash () as a normal graphic character, not an escape character.</td>
<td>OFF</td>
</tr>
<tr>
<td>-nobss_init</td>
<td>Disables placement of zero-initialized variables in BSS (using DATA section)</td>
<td>OFF</td>
</tr>
<tr>
<td>-nolib_inline</td>
<td>Disables inline expansion of intrinsic functions.</td>
<td>ON</td>
</tr>
<tr>
<td>Argument</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-nologo</td>
<td>Suppresses compiler version information.</td>
<td>ON</td>
</tr>
<tr>
<td>-[no]stack_temps</td>
<td>Allocates temporary array in the heap (default) or on the runtime stack with -stack_temps.</td>
<td>OFF</td>
</tr>
<tr>
<td>-nus</td>
<td>Disables appending an underscore to external subroutine names.</td>
<td>OFF</td>
</tr>
<tr>
<td>-nusfile</td>
<td>Disables appending an underscore to subroutine names listed in file.</td>
<td>OFF</td>
</tr>
<tr>
<td>-O, -O1, -O2 IA-32 compiler</td>
<td>Optimize for speed. Disable -fp. option.</td>
<td>OFF</td>
</tr>
<tr>
<td>-O1 Itanium compiler</td>
<td>Optimizes to favor code size: turns off software pipelining to reduce code size. Enables the same optimizations as -O except for loop unrolling and software pipelining.</td>
<td>OFF</td>
</tr>
<tr>
<td>-O2</td>
<td>Optimizes for speed. Disables -fp. option.</td>
<td>ON</td>
</tr>
<tr>
<td>-O0</td>
<td>Disables optimizations.</td>
<td>OFF</td>
</tr>
<tr>
<td>-O3</td>
<td>Enables -O2 option with more aggressive optimization, for example, loop transformation. Optimizes for maximum speed, but may not improve performance for some programs.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-Ob{0</td>
<td>1</td>
<td>2}</td>
</tr>
<tr>
<td></td>
<td>-Ob0: disable inlining</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Ob1: disables inlining unless -ip or -Ob2 is specified. Enables inlining of functions.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Ob2: Enables inlining of any function. However, the compiler decides which functions are inlined. This option enables interprocedural optimizations and has the same effect as specifying the -ip option.</td>
<td></td>
</tr>
<tr>
<td>-ofile</td>
<td>Indicates the executable file name in file; for example, -omyfile. Combined with -S, indicates assembly listing file name. Combined with -c, indicates object file name.</td>
<td>OFF</td>
</tr>
<tr>
<td>-onetrip</td>
<td>Executes any DO loop at least once. (Identical to the -1 option.)</td>
<td>OFF</td>
</tr>
<tr>
<td>-openmp</td>
<td>Enables the parallelizer to generate multithreaded code based on the OpenMP directives. This option implies that -fpp and -auto are ON.</td>
<td>OFF</td>
</tr>
<tr>
<td>-openmp_report{0</td>
<td>1</td>
<td>2}</td>
</tr>
<tr>
<td>-openmp_stubs</td>
<td>Sets compilation of the OpenMP programs to be in sequential mode. The OpenMP directives are ignored and a stub OpenMP library is linked (sequentially).</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>--------</td>
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</tr>
<tr>
<td><code>-opt_report</code></td>
<td>Generates optimizations report and directs to stderr unless <code>-opt_report_file</code> is specified.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-opt_report_file filename</code></td>
<td>Specifies the <code>filename</code> to hold the optimizations report.</td>
<td>OFF</td>
</tr>
<tr>
<td>`-opt_report_level {min</td>
<td>med</td>
<td>max}`</td>
</tr>
<tr>
<td><code>-opt_report_phase phase</code></td>
<td>Specifies the optimization to generate the report for. Can be specified multiple times on the command line for multiple optimizations.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-opt_report_help</code></td>
<td>Prints to the screen all available phases for <code>-opt_report_phase</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-opt_report_routine routine_substring</code></td>
<td>Generates reports from all routines with names containing the <code>substring</code> as part of their name. If not specified, reports from all routines are generated.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-P</code></td>
<td>Preprocesses the fpp files and writes the results to files named according to the compilers default file-naming conventions.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-pad, -nopad</code></td>
<td>Enables/disables changing variable and array memory layout.</td>
<td><code>-nopad</code></td>
</tr>
<tr>
<td><code>-pad_source</code></td>
<td>Enables the acknowledgment of blanks at the end of a line.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td><code>-parallel</code></td>
<td>Enables the auto-parallelizer to generate multithreaded code for loops that can be safely executed in parallel.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-par_threshold</code></td>
<td>Sets a threshold for the auto-parallelization of loops based on the probability of profitable execution of the loop in parallel, ( n = 0 ) to 100.</td>
<td>( n = 75 )</td>
</tr>
<tr>
<td>`-par_report{0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><code>-pc32</code></td>
<td>Enables floating-point significand precision control as follows: <code>-pc32</code> to 24-bit significand.</td>
<td><code>-pc80</code></td>
</tr>
<tr>
<td><code>-pc64</code></td>
<td><code>-pc64</code> to 53-bit significand, and</td>
<td></td>
</tr>
<tr>
<td><code>-pc80</code></td>
<td><code>-pc80</code> to 64-bit significand</td>
<td></td>
</tr>
<tr>
<td><code>-pg</code></td>
<td>Compile and link for function profiling with Linux gprof tool.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-posixlib</code></td>
<td>Enables linking to the POSIX* library (<code>libPOSF90.a</code>) in the compilation.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-prec_div</code></td>
<td>Disables floating point division-to-multiplication optimization resulting in more accurate division results. Slight speed impact.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-prefetch[-]</code></td>
<td>Enables or disables prefetch insertion (requires <code>-O3</code>).</td>
<td>ON</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-prof_dir dir</td>
<td>Specifies the directory to hold profile information in the profiling output files, *.dyn and *.dpi.</td>
<td>OFF</td>
</tr>
<tr>
<td>-prof_gen</td>
<td>Instruments the program for profiling: to get the execution count of each basic block.</td>
<td>OFF</td>
</tr>
<tr>
<td>-prof_file file</td>
<td>Specifies file name for profiling summary file.</td>
<td>OFF</td>
</tr>
<tr>
<td>-prof_use</td>
<td>Enables the use of profiling dynamic feedback information during optimization.</td>
<td>OFF</td>
</tr>
<tr>
<td>-q</td>
<td>Suppresses compiler output to standard error, stderr.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Qdyncom &quot;blk1,blk2,...&quot;</td>
<td>Enables dynamic allocation of given COMMON blocks at run time.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Qinstall dir</td>
<td>Sets dir as a root directory for compiler installation.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Qlocation, tool, path</td>
<td>Sets path as the location of the tool specified by tool.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Qloccom &quot;blk1,blk2,...&quot;</td>
<td>Enables local allocation of given COMMON blocks at run time.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Qoption, tool, opts</td>
<td>Passes the options, opts, to the tool specified by tool.</td>
<td>OFF</td>
</tr>
<tr>
<td>-qp, -p</td>
<td>Compile and link for function profiling with UNIX* prof tool.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>`-r{8</td>
<td>16}`</td>
<td>Defines the KIND for real variables to be 8, or 16 bytes. By default, variables of type REAL (4) are used. <code>-r8</code>: change the size and precision of default REAL entities to DOUBLE PRECISION. Same as the <code>-autodouble</code>. <code>-r16</code>: change the size and precision of default REAL entities to REAL (KIND=16)</td>
</tr>
<tr>
<td><code>-rcd</code></td>
<td>IA-32 compiler Disables changing of rounding mode for floating-point-to-integer conversions.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-S</code></td>
<td>Produces an assembly output file.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-safe_cray_ptr</code></td>
<td>Specifies that Cray* pointers do not alias with other variables.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-save</code></td>
<td>Saves variables (static allocation) except local variables within a recursive routine. Opposite of <code>-auto</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-scalar_rep[-]</code></td>
<td>IA-32 compiler Enables or disables scalar replacement performed during loop transformations (requires <code>-O3</code>).</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-sox[-]</code></td>
<td>IA-32 compiler Enables or disables (default) saving of compiler options and version in the executable. Itanium compiler: accepted for compatibility only.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Status</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>--------</td>
</tr>
<tr>
<td><code>-shared</code></td>
<td>Instructs the compiler to build a Dynamic Shared Object (DSO) instead of an executable.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-static</code></td>
<td>Sets static linking of the shared libraries (.so).</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-syntax</code></td>
<td>Enables syntax check only. Same as <code>-y</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-Tffile</code></td>
<td>Compiles file as a Fortran source.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-tpp1</code></td>
<td>Itanium compiler</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-tpp2</code></td>
<td>Itanium compiler</td>
<td>ON</td>
</tr>
<tr>
<td>`-tpp{5</td>
<td>6</td>
<td>7}`</td>
</tr>
<tr>
<td><code>-u</code></td>
<td>Sets IMPLICIT NONE by default. Same as <code>-implicitnone</code>.</td>
<td>ON</td>
</tr>
<tr>
<td><code>-Uname</code></td>
<td>Removes a defined macro specified by name; equivalent to an #undef preprocessing directive.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-unroll[n]</td>
<td>Use n to set maximum number of times to unroll a loop. Omit n to let the compiler decide whether to perform unrolling or not. Use n = 0 to disable unroller. The Itanium compiler currently recognizes only n = 0; all other values are ignored.</td>
<td>ON</td>
</tr>
<tr>
<td>-uppercase</td>
<td>Sets the case of external linker symbols such as subroutine names to be uppercase characters.</td>
<td>OFF</td>
</tr>
<tr>
<td>-us</td>
<td>Appends (default) an underscore to external subroutine names.</td>
<td>ON</td>
</tr>
<tr>
<td>-use_asm</td>
<td>Produces objects through the assembler.</td>
<td>OFF</td>
</tr>
<tr>
<td>-V</td>
<td>Displays compiler version information.</td>
<td>OFF</td>
</tr>
<tr>
<td>-v</td>
<td>Shows driver tool commands and executes tools.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Vaxlib</td>
<td>Enables linking to portability library (libPEPCF90.a) in the compilation.</td>
<td>OFF</td>
</tr>
<tr>
<td>-vec_report{n}</td>
<td>Controls amount of vectorizer diagnostic information as follows: n = 0: no information n = 1: indicate vectorized /non-vectorized loops n = 2: indicate vectorized /non-vectorized loops n = 3: indicate vectorized /non-vectorized loops and prohibit data dependence information n = 4: indicate non-vectorized</td>
<td>-vec _report1</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>---------</td>
</tr>
<tr>
<td>n=5: indicate non-vectorized loops and the reason why they were not vectorized.</td>
<td>More...</td>
<td></td>
</tr>
<tr>
<td>-vms</td>
<td>Enables support for a certain set of extensions to Fortran that were introduced by Digital* VMS* and Compaq* Fortran compilers.</td>
<td>OFF</td>
</tr>
<tr>
<td>-w</td>
<td>Suppresses all warning messages.</td>
<td>OFF</td>
</tr>
<tr>
<td>-w90, -w95</td>
<td>Suppresses warning messages about Fortran features which are deprecated or obsoleted in Fortran 95.</td>
<td>OFF</td>
</tr>
<tr>
<td>-W{n}</td>
<td>Suppresses or displays all warning messages. n=0: suppresses all warnings n=1: displays all warnings (default).</td>
<td>-W1</td>
</tr>
<tr>
<td>-WB</td>
<td>On a bound check violation, issues a warning instead of an error.</td>
<td>OFF</td>
</tr>
<tr>
<td>-x{i</td>
<td>M</td>
<td>K</td>
</tr>
<tr>
<td>-X</td>
<td>Removes standard directories from the include file search.</td>
<td>OFF</td>
</tr>
<tr>
<td>-y</td>
<td>Enables syntax check only.</td>
<td>OFF</td>
</tr>
</tbody>
</table>
Compiler Options by Functional Groups Overview

Options entered on the command line change the compiler's default behavior, enable or disable compiler functionalities, and can improve the performance of your application. This section presents tables of compiler options grouped by Intel® Fortran Compiler functionality within these categories:

- Customizing Compilation Process Option Groups
- Language Conformance Option Groups
- Application Performance Optimizations

Key to the Tables

In each table:

- The functions are listed in alphabetical order
- The default status ON or default value is indicated; if not mentioned, the default is OFF
- The IA-32 or Itanium® architectures are indicated as follows:
  - not mentioned = used by both architectures
  - indicated in a row = used in the following rows exclusively by indicated architecture.

Each option group is described in detailed form in the sections of this documentation. Some options can be viewed as belonging to more than one group; for example, option -c that tells compiler to stop at creating an object file, can be viewed as monitoring either compilation or linking. In such cases, the options are mentioned in more than one group.

Alternate Tools and Locations
<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Qlocation, tool, path</td>
<td>Enables you to specify a path as the location of the specified tool (such as the assembler, linker, preprocessor, and compiler). See Specifying Alternate Tools and Locations.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Qoption, tool, opts</td>
<td>Passes the options specified by opts to a tool, where opts is a comma-separated list of options. See Passing Options to Other Tools.</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Preprocessing

See the Preprocessing section for more information.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-cpp{n}</td>
<td>Same as -fpp{n}.</td>
<td>OFF</td>
</tr>
<tr>
<td>-D name [=text]</td>
<td>Defines the macro name and associates it with the specified value. The default (-D name) defines a macro with value =1.</td>
<td>OFF</td>
</tr>
<tr>
<td>-E</td>
<td>Directs the preprocessor to expand your source file and write the result to standard output.</td>
<td>OFF</td>
</tr>
<tr>
<td>-EP</td>
<td>Same as -E but does not include #line directives in the output.</td>
<td>OFF</td>
</tr>
<tr>
<td>-F</td>
<td>Preprocesses to an indicated file. Directs the preprocessor to expand your source module and store the result in a file in the current directory.</td>
<td>OFF</td>
</tr>
<tr>
<td>-fpp{n}</td>
<td>Uses the fpp preprocessor on Fortran source files.</td>
<td>OFF</td>
</tr>
</tbody>
</table>
|          | n=0: disable CVF and #directives  
|          | n=1: enable CVF conditional compilation and # directives; when fpp runs, -fpp1 is the default  
|          | n=2: enable only #directives,  
|          | n=3: enable only CVF conditional compilation directives.                                                                                                                                             | (-fpp1 when fpp runs) |
| -Idir   | Adds directory dir to the include and module file search path.                                                                                                                                             | OFF     |
### Compiling

See detailed [Compiling](#) section.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-P</code></td>
<td>Directs the preprocessor to expand your source file and store the result in a file in the current directory.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-U name</code></td>
<td>Eliminates any definition <em>name</em> currently in effect.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-X</code></td>
<td>Removes standard directories from the include file search path.</td>
<td>OFF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-0f_check</code> IA-32 only</td>
<td>Avoid incorrect decoding of some <code>0f</code> instructions; enable the patch for the Pentium® <code>0f</code> erratum.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-align</code></td>
<td>Analyzes and reorders memory layout for variables and arrays.</td>
<td><code>-align</code></td>
</tr>
<tr>
<td><code>-noalign</code></td>
<td>Disables <code>-align</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-c</code></td>
<td>Compile to object only (<code>.o</code>), do not link.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-complex_limited_range[-]</code></td>
<td>Enables or disables (default) the use of the basic algebraic expansions of some complex arithmetic operations. This can enable some performance improvement in programs which use a lot of complex arithmetic operations at the loss of some exponent range.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-dynamic-linkerfile</code></td>
<td>Specifies in <em>file</em> a dynamic linker of choice, rather than default.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-falias</code></td>
<td>Assumes aliasing in program.</td>
<td>ON</td>
</tr>
<tr>
<td><code>-fno-alias</code></td>
<td>Assumes no aliasing in program.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-ffnalias</code></td>
<td>Assumes aliasing within functions.</td>
<td>ON</td>
</tr>
<tr>
<td><code>-fno-fnalias</code></td>
<td>Assumes no aliasing within functions, but assumes aliasing across calls.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-fp</code> IA-32 only</td>
<td>Disables using <code>ebp</code> as general purpose register in optimizations. Directs to use the <code>ebp</code>-based stack frame for all functions.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-I dir</code></td>
<td>Adds directory <em>dir</em> to the include and module file search path.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-Kpic</code>, <code>-KPIC</code> IA-32 only</td>
<td>Generate position-independent code.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>-module [path], -nomodule</td>
<td>Specifies the directory where the module files (extension .mod) are placed. Omitting this option or specifying -nomodule results in placing the .mod files in the directory where the source files are being compiled.</td>
<td></td>
</tr>
<tr>
<td>-nobss_init</td>
<td>Disable placement of zero-initialized variables in BSS (using Data).</td>
<td></td>
</tr>
<tr>
<td>-[no]stack _temps</td>
<td>Allocates temporary array in the heap (default) or on the runtime stack with -stack_temps.</td>
<td></td>
</tr>
<tr>
<td>-p, -qp</td>
<td>Compile and link for function profiling with UNIX* prof tool.</td>
<td></td>
</tr>
<tr>
<td>-pg</td>
<td>Compile and link for function profiling with Linux* gprof tool.</td>
<td></td>
</tr>
<tr>
<td>-Qinstall,dir</td>
<td>Sets root directory of compiler installation, indicated in dir to contain all compiler install files and subdirectories.</td>
<td></td>
</tr>
<tr>
<td>-S</td>
<td>Produce assembly file named file.s with optional code or source annotations. Do not link.</td>
<td></td>
</tr>
<tr>
<td>-sox[-]</td>
<td>Enable (default) or disable saving of compiler options and version in the executable.</td>
<td></td>
</tr>
<tr>
<td>-Tf file</td>
<td>Compile file as Fortran source.</td>
<td></td>
</tr>
<tr>
<td>-use_asm</td>
<td>Produces objects through the assembler.</td>
<td></td>
</tr>
<tr>
<td>-Zp{n}</td>
<td>Specifies alignment constraint for structures on n-byte boundary (n = 1, 2, 4, 8, 16). The -Zp16 option enables you to align Fortran structures such as common blocks.</td>
<td></td>
</tr>
</tbody>
</table>

### Linking

See detailed Linking section.
### Compilation Output

See the [Specifying Compilation Output](#) section for more information.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-c</td>
<td>Compile to object only (.o), do not link.</td>
<td>OFF</td>
</tr>
<tr>
<td>-fcode-asasm</td>
<td>Inserts code byte annotations in assembly file produced with -S.</td>
<td>OFF</td>
</tr>
<tr>
<td>-fsourc-asasm</td>
<td>Inserts high-level source code annotations in assembly file produced with -S.</td>
<td>OFF</td>
</tr>
</tbody>
</table>
### Debugging

See the [Debugging](#) section for more information.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-DD</code></td>
<td>Compiles debug statements indicated by a D or a d in column 1; if this option is not set these lines are treated as comments</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-DX</code></td>
<td>Compiles debug statements indicated by an X or an x in column 1; if this option is not set these lines are treated as comments.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-DY</code></td>
<td>Compiles debug statements indicated by a Y or a y in column 1; if this option is not set these lines are treated as comments.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-inline_debug_info</code></td>
<td>Keeps the source position of inline code instead of assigning the call-site source position to inlined code.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-g</code></td>
<td>Produces symbolic debug information in the object file.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-y, -syntax</code></td>
<td>Both perform syntax check only.</td>
<td>OFF</td>
</tr>
</tbody>
</table>
Libraries

See [detailed section on Libraries](#).

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-C90</td>
<td>Link with alternate I/O library for mixed output with the C language.</td>
<td>OFF</td>
</tr>
<tr>
<td>-i_dynamic</td>
<td>Enables to link Intel-provided libraries dynamically.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Ldir</td>
<td>Instructs linker to search dir for libraries.</td>
<td>OFF</td>
</tr>
<tr>
<td>-lname</td>
<td>Links with the library indicated in name.</td>
<td>OFF</td>
</tr>
<tr>
<td>-posixlib</td>
<td>Link with POSIX* library.</td>
<td>OFF</td>
</tr>
<tr>
<td>-shared</td>
<td>Instructions the compiler to build a Dynamic Shared Object (DSO) instead of an executable.</td>
<td>OFF</td>
</tr>
<tr>
<td>-static</td>
<td>Enables to link shared libraries (.so) statically.</td>
<td>OFF</td>
</tr>
<tr>
<td>-Vaxlib</td>
<td>Link with portability library.</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Diagnostics and Messages

See [Diagnostics and Messages](#) section for more information.

Runtime Diagnostics (IA-32 Compiler only)

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-C</td>
<td>Equivalent to: (–CA, –CB, –CS, –CU, –CV) extensive runtime diagnostics options.</td>
<td>OFF</td>
</tr>
<tr>
<td>-CA</td>
<td>Use in conjunction with –d{n}. Checks for nil pointers/allocatable array references at runtime.</td>
<td>OFF</td>
</tr>
<tr>
<td>-CB</td>
<td>Use in conjunction with –d{n}. Generates runtime code to check that array subscript and substring references are within declared bounds.</td>
<td>OFF</td>
</tr>
<tr>
<td>-CS</td>
<td>Use in conjunction with –d{n}. Generates runtime code that checks for consistent shape of intrinsic procedure.</td>
<td>OFF</td>
</tr>
<tr>
<td>-CU</td>
<td>Use in conjunction with –d{n}. Generates runtime code that causes a runtime error if variables are used without being initialized.</td>
<td>OFF</td>
</tr>
</tbody>
</table>
### Compiler Information Messages

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-nologo</code></td>
<td>Disables the display of the compiler version (or sign-on) message: compiler ID, version, copyright years.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-help</code></td>
<td>You can print a list and brief description of the most useful compiler driver options by specifying the <code>-help</code> option on the command line.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-V</code></td>
<td>Displays compiler version information.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-v</code></td>
<td>Shows driver tool commands and executes tools.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-dryrun</code></td>
<td>Shows driver tool commands, but does not execute tools.</td>
<td>OFF</td>
</tr>
</tbody>
</table>

### Comment and Warning Messages

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-cm</code></td>
<td>Suppresses all comment messages.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-cerrs[-]</code></td>
<td>Enables/disables (default) a terse format for diagnostic messages, for example: &quot;file&quot;, line no : error message</td>
<td><code>-cerrs</code></td>
</tr>
<tr>
<td><code>-w</code></td>
<td>Suppresses all warning messages.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-w90, -w95</code></td>
<td>Suppresses warning messages about Fortran features which are deprecated or obsoleted in Fortran 95.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-W{n}</code></td>
<td>Suppresses or displays all warning messages generated by preprocessing and compilation. n=0: suppresses all warnings n=1: displays all warnings (default).</td>
<td><code>-W1</code></td>
</tr>
</tbody>
</table>
Error Messages

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-e90, -e95</td>
<td>Enable issuing of errors rather than warnings for features that are non-standard Fortran.</td>
<td>OFF</td>
</tr>
<tr>
<td>-q</td>
<td>Suppresses compiler output to standard error, stderr.</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Data Type

See more details in Setting Data Types and Sizes.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-autodouble</td>
<td>Sets the default size of real numbers to 8 bytes; same as -r8.</td>
<td>OFF</td>
</tr>
<tr>
<td>-i{2</td>
<td>4</td>
<td>8}</td>
</tr>
<tr>
<td>-r{4</td>
<td>8</td>
<td>16}</td>
</tr>
</tbody>
</table>

Source Program

See more details in Source Program Features.
<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-l</td>
<td>Same as -onetrip.</td>
<td>OFF</td>
</tr>
<tr>
<td>-132</td>
<td>Enables fixed form source lines to contain up to 132 characters.</td>
<td>OFF</td>
</tr>
<tr>
<td>-ansi_alias[-]</td>
<td>Enables (default) or disables assumption of the program's ANSI conformance. Provides cross-platform compatibility.</td>
<td>-ansi_alias</td>
</tr>
<tr>
<td>-ansi_alias[-]</td>
<td>Enables (default) or disables assumption of the program's ANSI conformance. Provides cross-platform compatibility.</td>
<td>-ansi_alias</td>
</tr>
<tr>
<td>-dps, -nodps</td>
<td>Enables (default) or disabled DEC* parameter statement recognition.</td>
<td>-dps</td>
</tr>
<tr>
<td>-extend_source</td>
<td>Enables extended (132-character) source lines. Same as -132.</td>
<td>OFF</td>
</tr>
<tr>
<td>-FI</td>
<td>Specifies that all the source code is in fixed format; this is the default except for files ending with the suffix .f, .ftn, .for.</td>
<td>OFF</td>
</tr>
<tr>
<td>-FR</td>
<td>Specifies that all the source code is in Fortran free format; this is the default for files ending with the suffix .f90.</td>
<td>OFF</td>
</tr>
<tr>
<td>-lowercase</td>
<td>Controls the case of routine names and external linker symbols to all lowercase characters.</td>
<td>ON</td>
</tr>
<tr>
<td>-nbs</td>
<td>Treats backslash () as a normal graphic character, not an escape character. This may be necessary when transferring programs from non-UNIX* environments, for example from VAX* VMS*. For the effects of the escape character, see the Escape Characters.</td>
<td>OFF</td>
</tr>
<tr>
<td>-nus[file]</td>
<td>Do not append an underscore to subroutine names listed in file. Useful when linking with C routines.</td>
<td>OFF</td>
</tr>
<tr>
<td>-onetrip</td>
<td>Compiles DO loops at least once if reached (by default, Fortran 95 DO loops are not performed at all if the upper limit is smaller than the lower limit). Same as -1.</td>
<td>OFF</td>
</tr>
<tr>
<td>-pad_source</td>
<td>Enforces the acknowledgment of blanks at the end of a line.</td>
<td>OFF</td>
</tr>
</tbody>
</table>
Arguments and Variables

See more details in Setting Arguments and Variables.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-align</td>
<td>Analyze and reorder memory layout for variables and arrays.</td>
<td>-align</td>
</tr>
<tr>
<td>-noalign</td>
<td>Disables -align.</td>
<td>OFF</td>
</tr>
<tr>
<td>-auto</td>
<td>Makes all local variables AUTOMATIC. Causes all variables to be allocated on the stack, rather than in local static storage.</td>
<td>OFF</td>
</tr>
</tbody>
</table>
### Common Blocks

See [Allocating Common Blocks](#) for more information.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-Qdyncom&quot;blk1, blk2, ...&quot;</code></td>
<td>Dynamically allocates COMMON blocks at run time.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-Qloccom&quot;blk1, blk2, ...&quot;</code></td>
<td>Enables local allocation of given COMMON blocks at run time.</td>
<td>OFF</td>
</tr>
</tbody>
</table>

### Setting Optimization Level

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-auto_scalar</code></td>
<td>Causes scalar variables of rank 0, except for variables of the COMPLEX or CHARACTER types, to be allocated on the stack, rather than in local static storage. Enables the compiler to make better choices concerning variables that should be kept in registers during program execution. On by default.</td>
<td>ON</td>
</tr>
<tr>
<td><code>-common_args</code></td>
<td>Assumes &quot;by reference&quot; subprogram arguments may have aliases of one another.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-implicitnone</code></td>
<td>Enables the default IMPLICIT NONE.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-safe_cray_ptr</code></td>
<td>Specifies that Cray pointers do not alias with other variables.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-save</code></td>
<td>Forces the static allocation of variables in static storage, except local variables within a recursive routine. If a routine is invoked more than once, this option forces the local variables to retain their values from the last invocation terminated. Opposite of <code>-auto</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-u</code></td>
<td>Enables the default IMPLICIT NONE. Same as <code>-implicitnone</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-zero</code></td>
<td>Initializes all data to zero. It is most commonly used in conjunction with <code>-save</code>.</td>
<td>OFF</td>
</tr>
</tbody>
</table>
See the Optimization Levels section for more information.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-O1</td>
<td>IA-32 compiler: Optimizes for speed. Disables -fp option. Itanium® compiler: Turns off software pipelining to reduce code size. Optimizes to favor code size. Enables the same optimizations as -O2 except for loop unrolling. Generally, -O2 is recommended over -O1.</td>
<td>OFF</td>
</tr>
<tr>
<td>-O, -O2</td>
<td>Optimizes for speed. Disables -fp option.</td>
<td>-O2</td>
</tr>
<tr>
<td>-O3</td>
<td>Enables -O2 option with more aggressive optimization and sets high-level optimizations, including loop transformation, OpenMP, and prefetching. High-level optimizations use the properties of source code constructs such as loops and arrays in applications written in high-level programming languages. Optimizes for maximum speed, but may not improve performance for some programs.</td>
<td>OFF</td>
</tr>
<tr>
<td>-O0</td>
<td>Disables optimizations -O1, -O2 and -O3. Enables option -fp.</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Floating-point Arithmetic Precision

See Floating-point Arithmetic Optimizations for more information.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-fp_port</td>
<td>IA-32 only</td>
<td>Rounds floating-point results at assignments and casts. Some speed impact.</td>
</tr>
<tr>
<td>-ftz[-]</td>
<td>Itanium®-based systems</td>
<td>Flushes denormal results (floating-point values smaller than smallest normalized floating-point number) to zero. Turned on by -O3. Use this option when the denormal values are not critical</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-IFP_fma [-]</td>
<td>Enables/disables the contraction of floating-point multiply and add/subtract operations into a single operation.</td>
<td>-IFP_fma</td>
</tr>
<tr>
<td>-IPF_fp speculatiodmode</td>
<td>Sets the compiler to speculate on fp operations in one of the following modes: fast: speculate on fp operations; safe: speculate on fp operations only when it is safe; strict: enables the compiler's speculation on floating-point operations preserving floating-point status in all situations; same as off in the current version. off: disables fp speculation.</td>
<td>-IPF_fpc64_speculationfasp</td>
</tr>
<tr>
<td>-IPF_flt_eval_method0</td>
<td>Directs the compiler to evaluate the expressions involving floating-point operands in the precision indicated by the program. (-IPF_flt_eval_method2 is not supported in the current version.)</td>
<td>OFF</td>
</tr>
<tr>
<td>-IFP_fltacc [-]</td>
<td>Disables optimizations that affect floating-point accuracy. The default is to enable such optimizations.</td>
<td>-IFP_fltacc-</td>
</tr>
<tr>
<td>-mp</td>
<td>Maintains declared precision and ensures that floating-point arithmetic conforms more closely to the ANSI and IEEE* 754 standards. See details in the Maintaining and Restricting FP Arithmetic Precision.</td>
<td>OFF</td>
</tr>
<tr>
<td>-mp1</td>
<td>Restricts floating-point precision to be closer to declared precision. Some speed impact, but less than -mp. See details in the Maintaining and Restricting FP Arithmetic Precision.</td>
<td>OFF</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>-pc{32</td>
<td>64</td>
<td>80}</td>
</tr>
<tr>
<td>IA-32 only</td>
<td>-pc32 to 24-bit significand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-pc64 to 53-bit significand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Default)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-pc80 to 64-bit significand</td>
<td></td>
</tr>
<tr>
<td>-prec_div</td>
<td>Disables floating point division-to-multiplication optimization resulting in</td>
<td>OFF</td>
</tr>
<tr>
<td>IA-32 only</td>
<td>more accurate division results. Slight speed impact.</td>
<td></td>
</tr>
<tr>
<td>-rcd</td>
<td>Disables changing of rounding mode for floating-point-to-integer conversions.</td>
<td>OFF</td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Optimizing for Specific Processors and Extensions

See [Optimizing for Specific Processors](#) for more information.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-tpp1</td>
<td>Targets optimization to the Intel® Itanium® processor for best performance.</td>
<td>OFF</td>
</tr>
<tr>
<td>Itanium®-based systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-tpp2</td>
<td>Targets optimization to the Intel® Itanium® 2 processor for best performance. Generated code is compatible with the Itanium processor.</td>
<td>-tpp2</td>
</tr>
<tr>
<td>Itanium-based systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-tpp5</td>
<td>Optimizes for the Intel® Pentium® processor. Enables best performance for Pentium® processor</td>
<td>OFF</td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-tpp6</td>
<td>Optimizes for the Intel Pentium Pro, Pentium II, and Pentium III processors. Enables best performance for the above processors.</td>
<td>OFF</td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-tpp7</td>
<td>Optimizes for the Intel Pentium 4 and Intel® Xeon(TM) processors. Requires the RedHat version 7.1 and support of Streaming SIMD Extensions 2. Enables best performance for Pentium 4 processor</td>
<td>-tpp7</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Default</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>`-ax{i</td>
<td>M</td>
<td>K</td>
</tr>
<tr>
<td>IA-32 only</td>
<td>i Intel Pentium Pro, Pentium II processors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M Intel Pentium with MMX(TM) technology processor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>K Intel Pentium III processor (Streaming SIMD Extensions)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W Intel Pentium 4, Intel Xeon processors, and Intel® Pentium® M processor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>In addition, <code>-ax</code> generates IA-32 generic code. The generic code is usually slower.</td>
<td></td>
</tr>
<tr>
<td>`-x{i</td>
<td>M</td>
<td>K</td>
</tr>
<tr>
<td>IA-32 only</td>
<td>i Intel Pentium Pro, Pentium II processors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M Intel Pentium with MMX technology processor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>K Intel Pentium III processor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W Intel Pentium 4, Intel Xeon processors, and Intel® Pentium® M processor</td>
<td></td>
</tr>
</tbody>
</table>

### Interprocedural Optimizations

See [Interprocedural Optimizations (IPO)](#) section for more information.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-ip</code></td>
<td>Enables single-file interprocedural optimizations. Enhances inline function expansion.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-ip_no_inlining</code></td>
<td>Disables full or partial inlining that would result from the <code>-ip</code> interprocedural optimizations. Requires <code>-ip</code> or <code>-ipo</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-ip_no_pinlining</code></td>
<td>IA-32 only Disables partial inlining. Requires <code>-ip</code> or <code>-ipo</code>.</td>
<td>OFF</td>
</tr>
<tr>
<td><code>-ipo</code></td>
<td>Enables interprocedural optimization across files. Compile all objects over entire program with multifile interprocedural optimizations. Enhances multifile optimization; multifile inline function expansion, interprocedural constant and function characteristics propagation, monitoring module-level static variables; dead code elimination.</td>
<td>OFF</td>
</tr>
</tbody>
</table>
Profile-guided Optimizations

See detailed Profile-guided Optimizations section.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-fnsplit [-]</td>
<td>Itanium® compiler</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>Disables function splitting, which is enabled by <code>-prof_use.</code></td>
<td></td>
</tr>
</tbody>
</table>
### High-level Language Optimizations

See detailed [High-level Language Optimizations (HLO)](HLO) section.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
</table>
| -prof_dir dir
dir            | Specifies the directory to hold profile information in the profiling output files, *.dyn and *.dpi. | OFF     |
| -prof_file file file | Specifies file name for profiling summary file.                          | OFF     |
| -prof_gen       | Instruments the program for profiling: to get the execution count of each basic block. | OFF     |
| -prof_use       | Enables the use of profiling dynamic feedback information during optimization. Profiles the most frequently executed areas and increases effectiveness of IPO. | OFF     |

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ivdep_parallel Itanium® compiler</td>
<td>Indicates there is absolutely no loop-carried memory dependency in the loop where IVDEP directive is specified.</td>
<td>OFF</td>
</tr>
<tr>
<td>-prefetch[-] IA-32 only</td>
<td>Enables or disables prefetch insertion (requires -O3). Reduces the wait time; optimum use is determined empirically.</td>
<td>-prefetch</td>
</tr>
<tr>
<td>-scalar_rep[-] IA-32 only</td>
<td>Enables (default) or disables scalar replacement performed during loop transformations (requires -O3). Eliminates all loads and stores of that variable. Increases register pressure.</td>
<td>-scalar_rep</td>
</tr>
<tr>
<td>-unroll[n] n omitted: compiler decides whether to perform unrolling or not.</td>
<td>Eliminates some code; hides latencies; can increase code size. For Itanium®-based applications, –unroll[o] is used only for compatibility.</td>
<td>-unroll</td>
</tr>
</tbody>
</table>

-prof_dir dir
dir            | Specifies the directory to hold profile information in the profiling output files, *.dyn and *.dpi. | OFF     |
| -prof_file file file | Specifies file name for profiling summary file.                          | OFF     |
| -prof_gen       | Instruments the program for profiling: to get the execution count of each basic block. | OFF     |
| -prof_use       | Enables the use of profiling dynamic feedback information during optimization. Profiles the most frequently executed areas and increases effectiveness of IPO. | OFF     |
## Parallelization

See detailed [Parallelization](#) section.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-openmp</td>
<td>Enables the parallelizer to generate multi-threaded code based on the OpenMP* directives. Enables parallel execution on both uni- and multiprocessor systems. Requires -fpp.</td>
<td>OFF</td>
</tr>
<tr>
<td>-openmp_report{0</td>
<td>1</td>
<td>2}</td>
</tr>
<tr>
<td>-openmp_stubs</td>
<td>Enables to compile OpenMP programs in sequential mode. The OpenMP directives are ignored and a stub OpenMP library is linked (sequentially).</td>
<td>OFF</td>
</tr>
<tr>
<td>-parallel</td>
<td>Enables the auto-parallelizer to generate multithreaded code for loops that can be safely executed in parallel.</td>
<td>OFF</td>
</tr>
<tr>
<td>-par_report{0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>-par_threshold{n}</td>
<td>Sets a threshold for the auto-parallelization of loops based on the probability of profitable execution of the loop in parallel, n=0 to 100.</td>
<td>n=75</td>
</tr>
</tbody>
</table>
## Vectorization (IA-32 only)

See detailed [Vectorization](#) section.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
</table>
| `-ax{i|M|K|W}` IA-32 only | Generates, on a single binary, code specialized to the extensions specified by the codes:  
  i Intel Pentium Pro, Pentium II processors  
  M Intel Pentium with MMX technology processor  
  K Intel Pentium III processor  
  W Intel Pentium 4 and Intel Xeon(TM) processors  
In addition, `-ax` generates IA-32 generic code. The generic code is usually slower.  

☐ **Note:** `-axi` is not a vectorizer option. | OFF     |
| `-x{i|M|K|W}` IA-32 only | Generate specialized code to run exclusively on the processors supporting the extensions indicated by the codes:  
  i Intel Pentium Pro, Pentium II processors  
  M Intel Pentium with MMX technology processor  
  K Intel Pentium III processor  
  W Intel Pentium 4 and Intel Xeon processors  

☐ **Note:** `-xi` is not a vectorizer option. | OFF     |
| `-vec_report {0|1|2|3|4|5}` IA-32 only | Controls the diagnostic messages from the vectorizer as follows:  
  n = 0: no information  
  n = 1: indicates vectorized /non-vectorized loops  
  n = 2: indicates vectorized /non-vectorized loops  
  n = 3: indicates vectorized /non-vectorized loops and prohibit data dependence information  
  n = 4: indicates non-vectorized loops  

☐ **vec_report1** |
Optimization Reports

See detailed Optimizer Report Generation.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>-opt_report</td>
<td>Generates optimizations report and directs to stderr unless -opt_report_file is specified.</td>
<td>OFF</td>
</tr>
<tr>
<td>-opt_report_file filename</td>
<td>Specifies the filename to hold the optimizations report.</td>
<td>OFF</td>
</tr>
<tr>
<td>-opt_report_level min</td>
<td>med</td>
<td>max}</td>
</tr>
<tr>
<td>-opt_report_phase phase</td>
<td>Specifies the optimization to generate the report for. Can be specified multiple times on the command line for multiple optimizations.</td>
<td>OFF</td>
</tr>
<tr>
<td>-opt_report_help</td>
<td>Prints to the screen all available phases for -opt_report_phase.</td>
<td>OFF</td>
</tr>
<tr>
<td>-opt_report_routine routine_substring</td>
<td>Generates reports from all routines with names containing the substring as part of their name. If not specified, reports from all routines are generated.</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Windows* to Linux* Options Cross-reference

This section provides cross-reference table of the Intel® Fortran Compiler options used on the Windows* and Linux* operating systems. The options described can be used for compilations targeted to either IA-32 or Itanium®-based applications or both. See Conventions Used in the Options Quick Guide Tables.

- Options specific to IA-32 architecture
- Options specific to the Itanium® architecture
All other options are available for both IA-32 and Itanium architectures.

**Note**
The table is based on the alphabetical order of compiler options for Linux.

**Note**
The value in the Default column is used for both Windows and Linux operating systems unless indicated otherwise.

<table>
<thead>
<tr>
<th>Windows Option</th>
<th>Linux Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/QI0f[ ]</td>
<td>-Of_check</td>
<td>Enables a software patch for Pentium® processor 0f erratum.</td>
</tr>
<tr>
<td>IA-32 only</td>
<td>IA-32 only</td>
<td></td>
</tr>
<tr>
<td>/1</td>
<td>-1</td>
<td>Executes any DO loop at least once.</td>
</tr>
<tr>
<td>/4L {72</td>
<td>80</td>
<td>132}</td>
</tr>
<tr>
<td>/align</td>
<td>-align</td>
<td>Analyzes and reorders memory layout for variables and arrays.</td>
</tr>
<tr>
<td>/align-</td>
<td>-noalign</td>
<td>Disables (-align)</td>
</tr>
<tr>
<td>/Qansi_alias [-]</td>
<td>-ansi_alias [ ]</td>
<td>Enables (default) or disables assumption of the programs ANSI conformance.</td>
</tr>
<tr>
<td>/Qauto</td>
<td>-auto</td>
<td>Makes all local variables AUTOMATIC.</td>
</tr>
<tr>
<td>/Qautodouble</td>
<td>-autodouble</td>
<td>Sets the default size of real numbers to 8 bytes; same as (-r8).</td>
</tr>
<tr>
<td>/Qauto_scalar</td>
<td>-auto_scalar</td>
<td>Makes scalar local variables AUTOMATIC.</td>
</tr>
<tr>
<td>Command</td>
<td>Option</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>/Qax{i</td>
<td>M</td>
<td>K</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>-Bdynamic</td>
<td>Used with -l name (see in this table), enables dynamic linking of libraries at run time. Compared to static linking, results in smaller executables.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>-Bstatic</td>
<td>Enables linking a user's library statically.</td>
</tr>
<tr>
<td>/c</td>
<td>-c</td>
<td>Stops the compilation process after an object file (.o) has been generated.</td>
</tr>
<tr>
<td>/C</td>
<td>-C</td>
<td>Enable extensive runtime error checking. Equivalent to: -CA, -CB, -CS, -CU, or -CV runtime diagnostics options.</td>
</tr>
<tr>
<td>/CA</td>
<td>-CA</td>
<td>Generates code check at runtime to ensure that referenced pointers and allocatable arrays are not nil. Should be used in conjunction with -d{n}.</td>
</tr>
<tr>
<td>/CB</td>
<td>-CB</td>
<td>Generates code to check that array subscript and substring references are within declared bounds. Should be used in conjunction with -d{n}.</td>
</tr>
<tr>
<td>/CS</td>
<td>-CS</td>
<td>Generates code to check the shapes of array arguments to intrinsic procedures. Should be used in conjunction with -d{n}.</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>/CU IA-32 only</td>
<td>Generates code that causes a runtime error if variables are used without being initialized. Should be used in conjunction with -d{n}.</td>
<td></td>
</tr>
<tr>
<td>-CU IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/CV IA-32 only</td>
<td>On entry to a subprogram, tests the correspondence between the actual arguments passed and the dummy arguments expected. Both calling and called code must be compiled with -CV for the checks to be effective. Should be used in conjunction with -d{n}.</td>
<td></td>
</tr>
<tr>
<td>-CV IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/C90</td>
<td>Links with an alternative I/O library (libCEPCF90.a) that supports mixed input and output with C on the standard streams.</td>
<td></td>
</tr>
<tr>
<td>-C90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/cerrs[-]</td>
<td>Enables/disables errors and warning messages to be printed in a terse format.</td>
<td></td>
</tr>
<tr>
<td>-cerrs[-]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/cm</td>
<td>Suppresses all comment messages.</td>
<td></td>
</tr>
<tr>
<td>-cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qcommon_args</td>
<td>Assumes by reference subprogram arguments may have aliases of one another.</td>
<td></td>
</tr>
<tr>
<td>-common_args</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qcomplex_limited_range[-]</td>
<td>Enables or disables (default) the use of the basic algebraic expansions of some complex arithmetic operations. This can enable some performance improvement in programs which use a lot of complex arithmetic operations at the loss of some exponent range.</td>
<td></td>
</tr>
<tr>
<td>-complex_limited_range[-]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qcpp[n]</td>
<td>Same as -fpp.</td>
<td></td>
</tr>
<tr>
<td>-cpp[n]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qd_lines</td>
<td>Compiles debugging statements indicated by the letter D in column 1 of the source code.</td>
<td></td>
</tr>
<tr>
<td>-DD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qdx_lines</td>
<td>Compiles debugging statements indicated by the letters X in column 1 of the source code.</td>
<td></td>
</tr>
<tr>
<td>-DX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>/Qdy_lines</td>
<td>Compile debugging statements indicated by the letters Y in column 1 of the source code.</td>
<td></td>
</tr>
<tr>
<td>/d{n}</td>
<td>Sets diagnostics level as follows:</td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td>-d{n} IA-32 only</td>
<td></td>
</tr>
<tr>
<td>IIA-32 only</td>
<td>-d{n} IIA-32 only</td>
<td></td>
</tr>
<tr>
<td>/Dname [={#</td>
<td>text}]</td>
<td>Defines a macro name and associates it with the specified value.</td>
</tr>
<tr>
<td>/Qdps[-]</td>
<td>Enable (default) or disable DEC* parameter statement recognition.</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>-dryrun Show driver tool commands but do not execute tools.</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>-dynamic-linker (file) Specifies in file a dynamic linker of choice, rather than default.</td>
<td></td>
</tr>
<tr>
<td>/E</td>
<td>Preprocesses the source files and writes the results to _stdout. If the file name ends with capital F, the option is treated as fpp.</td>
<td></td>
</tr>
<tr>
<td>/4{Y</td>
<td>N}s</td>
<td>Enables/disables issuing of errors rather than warnings for features that are non-standard Fortran.</td>
</tr>
<tr>
<td>/EP</td>
<td>Preprocesses the source files and writes the results to stdout omitting the #line directives.</td>
<td></td>
</tr>
<tr>
<td>/Qextend_source</td>
<td>Enables extended (132-character) source lines. Same as -132.</td>
<td></td>
</tr>
<tr>
<td>/P</td>
<td>Preprocesses the source files and writes the results to file.</td>
<td></td>
</tr>
<tr>
<td>/Oa-</td>
<td>Assumes aliasing in program.</td>
<td></td>
</tr>
<tr>
<td>Option</td>
<td>Command Line</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>---------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>/Oa</td>
<td>-fno-alias</td>
<td>Assumes no aliasing in program.</td>
</tr>
<tr>
<td>/Ow</td>
<td>-ffnalias</td>
<td>Assumes aliasing within functions.</td>
</tr>
<tr>
<td>/Ow</td>
<td>-fno-fnalias</td>
<td>Assumes no aliasing within functions, but assumes aliasing across calls.</td>
</tr>
<tr>
<td>/Fac</td>
<td>-fcode-asm</td>
<td>Inserts code byte annotations in assembly file produced with -S.</td>
</tr>
<tr>
<td>/FAs</td>
<td>-fsource-asm</td>
<td>Inserts high-level source code annotations in assembly file produced with -S.</td>
</tr>
<tr>
<td>None</td>
<td>-fverbose-asm</td>
<td>Inserts compiler comments including compiler version and options in an assembly file. Enabled by default when producing an assembly file (with -S).</td>
</tr>
<tr>
<td>None</td>
<td>-fnoverbose-asm</td>
<td>Disables -fverbose-asm.</td>
</tr>
<tr>
<td>/FI</td>
<td>-FI</td>
<td>Specifies that the source code is in fixed format. This is the default for source files with the file extensions .for, .f, or .ftn.</td>
</tr>
<tr>
<td>/Qfnsplit-</td>
<td>-fnsplit-Itanium-based systems</td>
<td>Disables function splitting, which is enabled by -prof_use.</td>
</tr>
<tr>
<td>/Oy</td>
<td>-fp</td>
<td>Enables the Fortran preprocessor (fpp) on all Fortran source files prior to compilation. n=0 disable CVF and # directives, equivalent to no fpp. n=1 enable CVF conditional</td>
</tr>
<tr>
<td>/Qfp_port</td>
<td>-fp_port</td>
<td>Rounds floating-point results at assignments and casts. Some speed impact.</td>
</tr>
<tr>
<td>/Qfpp{n}</td>
<td>-fpp{n}</td>
<td>Enables the Fortran preprocessor (fpp) on all Fortran source files prior to compilation. n=0 disable CVF and # directives, equivalent to no fpp. n=1 enable CVF conditional</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>compilation and # directives; when fpp runs, -fpp1 is the default n=2 enable only # directives n=3 enable only CVF conditional directives</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/FR</td>
<td>-FR</td>
<td>Specifies that the source code is in Fortran 95 free format. This is the default for source files with the .f90 file extensions.</td>
</tr>
<tr>
<td>-Qftz[-] Itanium-based systems</td>
<td>-ftz[-] Itanium-based systems</td>
<td>Flushes denormal results to zero.</td>
</tr>
<tr>
<td>/ZI, /Z7</td>
<td>-g</td>
<td>Generates symbolic debugging information and line numbers in the object code for use by source-level debuggers.</td>
</tr>
<tr>
<td>/help</td>
<td>-help</td>
<td>Prints help message.</td>
</tr>
<tr>
<td>/4I{2</td>
<td>4</td>
<td>8}</td>
</tr>
<tr>
<td>None</td>
<td>-i_dynamic</td>
<td>Enables to link Intel-provided libraries dynamically.</td>
</tr>
<tr>
<td>/I</td>
<td>-I</td>
<td>Specifies an additional directory to search for include and module files whose names do not begin with a slash (/).</td>
</tr>
<tr>
<td>/4{Y</td>
<td>N}d</td>
<td>-implicitnone</td>
</tr>
<tr>
<td>/Qinline_debug_info</td>
<td>-inline_debug_info</td>
<td>Keep the source position of inline code instead of assigning the call-site source position to inlined code.</td>
</tr>
<tr>
<td>/Qip</td>
<td>-ip</td>
<td>Enables single-file interprocedural optimizations within a file.</td>
</tr>
<tr>
<td>/Qip_no_inlining</td>
<td>-ip_no_inlining</td>
<td>Disables full or partial inlining that would result from the -ip interprocedural optimizations. Requires -ip or -ipo.</td>
</tr>
<tr>
<td><code>/Qip_no_pinlining</code></td>
<td><code>-ip_no_pinlining</code></td>
<td>Disables partial inlining. Requires <code>-ip</code> or <code>-ipo</code>.</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>IA-32 only</td>
<td>IA-32 only</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><code>/QIPF_fma[-]</code></th>
<th><code>-IPF_fma[-]</code></th>
<th>Enables/disables the contraction of floating-point multiply and add/subtract operations into a single operation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itanium-based systems</td>
<td>Itanium-based systems</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><code>/QIPF_fp_speculationmode</code></th>
<th><code>-IPF_fp_speculationmode</code></th>
<th>Sets the compiler to speculate on fp operations in one of the following modes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itanium-based systems</td>
<td>Itanium-based systems</td>
<td><code>fast</code>: speculate on fp operations;</td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>safe</code>: speculate on fp operations only when it is safe;</td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>strict</code>: enables the compiler's speculation on floating-point operations preserving floating-point status in all situations;</td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>off</code>: disables the fp speculation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><code>/QIPF_flt_eval_method0</code></th>
<th><code>-IPF_flt_eval_method0</code></th>
<th>directs the compiler to evaluate the expressions involving floating-point operands in the precision indicated by the program.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itanium-based systems</td>
<td>Itanium-based systems</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><code>/QIPF_fltacc</code></th>
<th><code>-IPF_fltacc</code></th>
<th>Disables [enables] optimizations that affect floating-point accuracy. The default is to enable such optimizations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itanium-based systems</td>
<td>Itanium-based systems</td>
<td></td>
</tr>
</tbody>
</table>

| `/Qipo` | `-ipo` | Enables interprocedural optimization across files. Compile all objects over entire program with multifile interprocedural optimizations. |

| `/Qipo_c` | `-ipo_c` | Optimizes across files and produces a multifile object file. This option performs optimizations as `-ipo`, but stops prior to the final link stage, leaving an optimized object file. |

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Option</td>
<td>Syntax</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>/Qipo_obj</td>
<td>-ipo_obj</td>
<td>Forces the generation of real object files. Requires -ipo.</td>
</tr>
<tr>
<td>/Qipo_S</td>
<td>-ipo_S</td>
<td>Optimizes across files and produces a multifile assembly file. This option performs optimizations as -ipo, but stops prior to the final link stage, leaving an optimized assembly file.</td>
</tr>
<tr>
<td>/Qivdep_parallel</td>
<td>-ivdep_parallel</td>
<td>Indicates there is absolutely no loop-carried memory dependency in the loop where IVDEP directive is specified.</td>
</tr>
<tr>
<td>Itanium-based systems</td>
<td>-Kpic, -KPIC</td>
<td>Generates position-independent code.</td>
</tr>
<tr>
<td>None</td>
<td>-Ldir</td>
<td>Instructs linker to search dir for libraries.</td>
</tr>
<tr>
<td>None</td>
<td>-lname</td>
<td>Links with the library indicated in name.</td>
</tr>
<tr>
<td>/list</td>
<td>-list</td>
<td>Prints a source listing to stdout (typically, your terminal screen) without contents of INCLUDE files.</td>
</tr>
<tr>
<td>/list/show:include</td>
<td>-list</td>
<td>Prints a source listing to stdout with contents of include files expanded.</td>
</tr>
<tr>
<td>/Qlowercase</td>
<td>-lowercase</td>
<td>Changes routine names to lowercase characters which are uppercase by default. (Linux: also controls the external symbol names in lowercase.)</td>
</tr>
<tr>
<td>/Fmfilename</td>
<td>None</td>
<td>Instructs the linker to produce a map file.</td>
</tr>
<tr>
<td>/module[path], /nomodule</td>
<td>-module [path], -nomodule</td>
<td>Specifies the directory where the module files (extension .mod) are placed. Omitting this option or specifying -nomodule results in placing the .mod files in the directory where the source files are being compiled.</td>
</tr>
<tr>
<td>Option</td>
<td>Argument</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>/Op[-]</td>
<td>-mp</td>
<td>Maintains declared floating-point precision as well as conformance to the IEEE 754 standards for floating-point arithmetic. Optimization is reduced accordingly.</td>
</tr>
<tr>
<td>/Qprec</td>
<td>-mpl1</td>
<td>Restricts floating floating-point precision to be closer to declared precision. Some speed impact, but less than -mp.</td>
</tr>
<tr>
<td>/nbs</td>
<td>-nbs</td>
<td>Treats backslash () as a normal graphic character, not an escape character.</td>
</tr>
<tr>
<td>/Qnobss_init</td>
<td>-nobss_init</td>
<td>Disables placement of zero-initialized variables in BSS (using DATA section)</td>
</tr>
<tr>
<td>/Oi-</td>
<td>-nolib_inline</td>
<td>Disables inline expansion of intrinsic functions.</td>
</tr>
<tr>
<td>/nologo</td>
<td>-nologo</td>
<td>Suppresses compiler version information.</td>
</tr>
<tr>
<td>/[no] stack_temps</td>
<td>-[no] stack_temps</td>
<td>Allocates temporary array in the heap (default) or on the runtime stack with –stack_temps.</td>
</tr>
<tr>
<td>None</td>
<td>-nus</td>
<td>Disables appending an underscore to external subroutine names.</td>
</tr>
<tr>
<td>/us</td>
<td>None</td>
<td>Append an underscore to external subroutine names</td>
</tr>
<tr>
<td>/Od</td>
<td>-O0</td>
<td>Disables optimizations.</td>
</tr>
<tr>
<td>/O2</td>
<td>-O, -O1, -O2</td>
<td>Optimize for speed, but disable some optimizations that increase code size for a small speed benefit. For Itanium compiler, -O1 turns off software pipelining to reduce code size.</td>
</tr>
<tr>
<td>/O3</td>
<td>-O3</td>
<td>Enables –O2 option with more aggressive optimization, for example, loop transformation. Optimizes for maximum speed, but may not improve performance for some programs.</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>
| `/Ob{0|1|2}`     | Controls the compiler's inline expansion. The amount of inline expansion performed varies as follows:  
  - `-Ob0`: disable inlining  
  - `-Ob1`: disables inlining unless `-ip` or `-Ob2` is specified. Enables inlining of functions.  
  - `-Ob2`: Enables inlining of any function. However, the compiler decides which functions are inlined. This option enables interprocedural optimizations and has the same effect as specifying the `-ip` option. |
<p>| <code>/Fofilename</code>    | Name the object file or directory for multiple files.                       |
| <code>/Fafilename</code>    | None                                                                         |
| <code>/Fefilename</code>    | None                                                                         |
| <code>/Qonetrip</code>      | Executes any DO loop at least once. (Identical to the <code>-1</code> option.).          |
| <code>/Qopenmp</code>       | Enables the parallelizer to generate multithreaded code based on the OpenMP* directives. This option implies that <code>-fpp</code> is ON. |
| <code>/Qopenmp_report {0|1|2}</code> | Controls the OpenMP parallelizers diagnostic levels.                        |
| <code>/Qopenmp_stubs</code> | Enables to compile OpenMP programs in sequential mode. The OpenMP directives are ignored and a stub OpenMP library is linked (sequentially). |
| <code>/Qopt_report</code>   | Generates optimizations report and directs to stderr unless <code>-opt_report_file</code> is specified. |</p>
<table>
<thead>
<tr>
<th>Command</th>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/Qopt_report _filename</td>
<td>-opt_report _filename</td>
<td>Specifies the filename to hold the optimizations report.</td>
</tr>
<tr>
<td>/Qopt_report _help</td>
<td>-opt_report _help</td>
<td>Prints to the screen all available phases for -opt_report_phase.</td>
</tr>
<tr>
<td>/Qopt_report_level [min</td>
<td>med</td>
<td>max]</td>
</tr>
<tr>
<td>/Qopt_report _phase</td>
<td>-opt_report _phase</td>
<td>Specifies the optimization to generate the report for. Can be specified multiple times on the command line for multiple optimizations.</td>
</tr>
<tr>
<td>/Qopt_report_routine_routine _substring</td>
<td>-opt_report_routine_routine _substring</td>
<td>Generates reports from all routines with names containing the substring as part of their name. If not specified, reports from all routines are generated.</td>
</tr>
<tr>
<td>/P</td>
<td>-P</td>
<td>Preprocesses the fpp files and writes the results to files named according to the compilers default file-naming conventions.</td>
</tr>
<tr>
<td>/Qpad[-]</td>
<td>-pad</td>
<td>Enables/disables changing variable and array memory layout.</td>
</tr>
<tr>
<td>/Qpad_source</td>
<td>-pad_source</td>
<td>Enforces the acknowledgment of blanks at the end of a line.</td>
</tr>
<tr>
<td>/Qparallel</td>
<td>-parallel</td>
<td>Enables the auto-parallelizer to generate multi-threaded code for loops that can be safely executed in parallel.</td>
</tr>
<tr>
<td>/Qpar_report [0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>/Qpar_threshold{n}</td>
<td>-par_threshold{n}</td>
<td>Sets a threshold for the auto-parallelization of loops based on the probability of profitable execution of the loop in parallel, n=0 to 100. This option is used for loops whose computation work volume</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>/Qpc {32</td>
<td>64</td>
<td>80}</td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Compile and link for function profiling with Linux gprof tool.</td>
<td></td>
</tr>
<tr>
<td>/4{Y</td>
<td>N}</td>
<td>Enables/disables (Windows) linking to the POSIX* library (libPOSF90.a) in the compilation.</td>
</tr>
<tr>
<td>posixlib</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qprof_div</td>
<td>Enables or disables prefetch insertion (requires -O3).</td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-prec_div</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qprefetch[-]</td>
<td>Enables floating point division-to-multiplication optimization resulting in more accurate division results. Slight speed impact.</td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-prefetch [-]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qprof_dirdir</td>
<td>Specifies the directory to hold profile information in the profiling output files, *.dyn and *.dpi.</td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-prof_dirdir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qprof_gen</td>
<td>Instruments the program for profiling: to get the execution count of each basic block.</td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-prof_gen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qprof_filefile</td>
<td>Specifies file name for profiling summary file.</td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-prof_filefile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qprof_use</td>
<td>Enables the use of profiling dynamic feedback information during optimization.</td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-prof_use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/q</td>
<td>Suppresses compiler output to standard error, stderr.</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-q</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qdyncomcom1 [,com2]</td>
<td>Enables dynamic allocation of given COMMON blocks at run time.</td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Qdyncom com1 [,com2]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Sets dir as a root directory for compiler installation.</td>
<td></td>
</tr>
<tr>
<td>/Qlocation, tool,path</td>
<td>Specifies an alternate version of a tool located at path.</td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>/Qloccom,com1 [,...,comn]</td>
<td><code>/Qloccom,com1 [,...,comn]</code> enables local allocation of given COMMON blocks at run time.</td>
<td></td>
</tr>
<tr>
<td>/Qoption,tool,opts</td>
<td><code>/Qoption,tool,opts</code> passes the options, opts, to the tool specified by tool.</td>
<td></td>
</tr>
<tr>
<td>None.</td>
<td><code>-qp, -p</code> Compile and link for function profiling with UNIX* prof tool.</td>
<td></td>
</tr>
<tr>
<td>/4R{4</td>
<td>8</td>
<td>16}</td>
</tr>
<tr>
<td></td>
<td>`-r{4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td><code>-r8: change the size and precision of default REAL entities to DOUBLE PRECISION. Same as the -autodouble. </code>-r16: change the size and precision of default REAL entities to REAL (KIND=16)</td>
<td></td>
</tr>
<tr>
<td>/Qrcd IA-32 only</td>
<td><code>/Qrcd IA-32 only</code> Disables changing of rounding mode for floating-point-to-integer conversions.</td>
<td></td>
</tr>
<tr>
<td>/S</td>
<td><code>/S</code> Produces an assembly output file with optional code.</td>
<td></td>
</tr>
<tr>
<td>/Qsafe_cray_ptr</td>
<td><code>/Qsafe_cray_ptr</code> Specifies that Cray* pointers do not alias with other variables.</td>
<td></td>
</tr>
<tr>
<td>/Qsave</td>
<td><code>/Qsave</code> Saves variables (static allocation), except local variables within a recursive routine. Opposite of -auto.</td>
<td></td>
</tr>
<tr>
<td>/Qscalar_rep IA-32 only</td>
<td><code>/Qscalar_rep IA-32 only</code> Enables or disables scalar replacement performed during loop transformations (requires -O3).</td>
<td></td>
</tr>
<tr>
<td>/Qsox[-] IA-32 only</td>
<td><code>/Qsox[-] IA-32 only</code> Enables or disables (default) saving of compiler options and version in the executable. Itanium compiler: accepted for compatibility only.</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td><code>-shared</code> Instructs the compiler to build a Dynamic Shared Object (DSO) instead of an executable.</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>-static</td>
<td>Enables to link shared libraries (.so) statically.</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>None</td>
<td>-syntax</td>
<td>Enables syntax check only. Same as -y.</td>
</tr>
<tr>
<td>/Tffile</td>
<td>-Tffile</td>
<td>Compile file as Fortran source.</td>
</tr>
<tr>
<td>/G1</td>
<td>-tpp1</td>
<td>Targets optimization to the Intel® Itanium® processor for best performance.</td>
</tr>
<tr>
<td>Itanium-based systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/G2</td>
<td>-tpp2</td>
<td>Targets optimization to the Intel® Itanium® 2 processor for best performance. Generated code is compatible with the Itanium processor.</td>
</tr>
<tr>
<td>Itanium-based systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/G{5</td>
<td>6</td>
<td>7}</td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td>-tpp6 optimizes for the Intel Pentium Pro, Pentium II, and Pentium III processors.</td>
</tr>
<tr>
<td>/4{Y</td>
<td>N}d</td>
<td>-u</td>
</tr>
<tr>
<td>/Uname</td>
<td>-Uname</td>
<td>Removes a defined macro; equivalent to an #undef preprocessing directive.</td>
</tr>
<tr>
<td>/Qunroll[n]</td>
<td>-unroll[n]</td>
<td>- Use n to set maximum number of times to unroll a loop.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Omit n to let the compiler decide whether to perform unrolling or not.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Use n = 0 to disable unroller. The Itanium compiler currently uses only n = 0; all other values are NOPs.</td>
</tr>
<tr>
<td>/Quppercase</td>
<td>-uppercase</td>
<td>Changes routine names to all uppercase characters.</td>
</tr>
<tr>
<td>None</td>
<td>-use_asm</td>
<td>Generates an assembly file and tells the assembler to generate the object file.</td>
</tr>
<tr>
<td>/Vstring</td>
<td>-V</td>
<td>Displays compiler version information.</td>
</tr>
<tr>
<td>None</td>
<td>-v</td>
<td>Shows driver tool commands and executes tools.</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>/4{Y</td>
<td>N}</td>
<td>-Vaxlib</td>
</tr>
<tr>
<td>portlib</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qvec_report</td>
<td>-vec_report</td>
<td>Controls amount of vectorizer diagnostic information as follows: n = 0: no information n = 1: indicate vectorizer loops n = 2: same as n = 1 plus non-vectorizer loops n = 3: same as n = 1 plus dependence information. n = 4: indicate non-vectorized loops n = 5: indicate non-vectorized loops and and the reason why they were not vectorized.</td>
</tr>
<tr>
<td>{n}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/Qvms</td>
<td>-vms</td>
<td>Enables support for I/O and DEC extensions to Fortran that were introduced by Digital* VMS and Compaq* Fortran compilers.</td>
</tr>
<tr>
<td>/w</td>
<td>-w</td>
<td>Suppresses all warning messages.</td>
</tr>
<tr>
<td>/W0</td>
<td>-W0</td>
<td>Disables display of warnings.</td>
</tr>
<tr>
<td>/W1</td>
<td>-W1</td>
<td>Displays warnings.</td>
</tr>
<tr>
<td>/w90, /w95</td>
<td>-w90, -w95</td>
<td>Suppresses warning messages about Fortran features which are deprecated or obsoleted in Fortran 95.</td>
</tr>
<tr>
<td>/WB</td>
<td>-WB</td>
<td>Issues a warning about compile time bound check violation.</td>
</tr>
<tr>
<td>/Qx{i</td>
<td>M</td>
<td>K</td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Command</td>
<td>Option</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>/X</td>
<td>−X</td>
<td>Removes standard directories from the include file search.</td>
</tr>
<tr>
<td>None</td>
<td>−y</td>
<td>Enables syntax check only.</td>
</tr>
<tr>
<td>/Qzero</td>
<td>−zero</td>
<td>Implicitly initializes to zero all data that is uninitialized otherwise. Used in conjunction with −save.</td>
</tr>
<tr>
<td>/Zp{1</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

- i = Pentium Pro & Pentium II processor information
- M = MMX(TM) instructions
- K = streaming SIMD extensions
- w = Pentium® 4 and Intel Xeon new instructions.
Getting Started with the Intel® Fortran Compiler

Invoking Intel® Fortran Compiler

The Intel® Fortran Compiler has the following variations:

- Intel® Fortran Compiler for 32-bit Applications is designed for IA-32 systems, and its command is `ifc`. The IA-32 compilations run on any IA-32 Intel processor and produce applications that run on IA-32 systems. This compiler can be optimized specifically for one or more Intel® IA-32 processors, from Intel® Pentium® to Pentium 4 to Celeron(TM) and Intel Xeon(TM) processors.

- Intel® Fortran Itanium® Compiler for Itanium®-based Applications, or native compiler, is designed for Itanium architecture systems, and its command is `efc`. This compiler runs on Itanium-based systems and produces Itanium-based applications. Itanium-based compilations can only operate on Itanium-based systems.

You can invoke compiler from:

- **compiler command line**
- **makefile command line**

Invoking from the Compiler Command Line

To invoke the Intel® Fortran Compiler from the command line requires these steps:

1. Set the environment variables
2. Issue the compiler command, `ifc` or `efc`

Setting the Environment Variables

Set the environment variables to specify locations for the various components. The Intel Fortran Compiler installation includes shell scripts that you can use to set environment variables. From the command line, execute the shell script that corresponds to your installation. With the default compiler installation, these scripts are located at:

**IA-32 systems:**

```
/opt/intel/compiler71/ia32/bin/ifcvars.sh
```
Itanium®-based systems:
/opt/intel/compiler71/ia64/bin/efcvars.sh

Running the Shell Scripts

To run the ifcvars.sh script on IA-32, enter the following on the command line:

```
prompt> ./opt/intel/compiler71/ia32/bin/ifcvars.sh
```

If you want the ifcvars.sh to run automatically when you start Linux®, edit your `.bash_profile` file and add the following line to the end of your file:

```
# set up environment for Intel compiler ifc
./opt/intel/compiler71/ia32/bin/ifcvars.sh
```

The procedure is similar for running the efcvars.sh shell script on Itanium®-based systems.

Command Line Syntax

The command for invoking the compiler depends on what processor architecture you are targeting the compiled file to run on, IA-32 or Itanium®-based applications. The following describes how to invoke the compiler from the command line for each targeted architecture.

- **Targeted for IA-32 architecture:**
  ```
prompt> ifc [options] file1.f [file2.f ..]
  ```

- **Targeted for Itanium® architecture:**
  ```
prompt> efc [options] file1.f [file2.f ..]
  ```

📝 Note
Throughout this manual, where applicable, command line syntax is given for both IA-32- and Itanium-based compilations as seen above.

<table>
<thead>
<tr>
<th><strong>options</strong></th>
<th>Indicates one or more command-line options. The compiler recognizes one or more letters preceded by a hyphen (-) as an option. Some options take arguments in the form of filenames, strings, letters, or numbers. Except where otherwise noted, you can enter a space between the option and its argument(s) or you can combine them.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>file1, file2 ..</strong></td>
<td>Indicates one or more files to be processed by the compilation system. You can specify more than one file. Use a space as a delimiter for multiple files. See Compiler Input Files.</td>
</tr>
</tbody>
</table>
Note
Specified options on the command line apply to all files. For example, in the following command line, the \texttt{-c} and \texttt{-w} options apply to both files \texttt{x.f} and \texttt{y.f}:

\begin{verbatim}
prompt> ifc -c x.f -w y.f  
prompt> efc -c x.f -w y.f
\end{verbatim}

Command Line with \texttt{make}

To specify a number of files with various paths and to save this information for multiple compilations, you can use makefiles. To use a makefile to compile your input files using the Intel\textregistered{} Fortran Compiler, make sure that /usr/bin and /usr/local/bin are on your path.

If you use the C shell, you can edit your \texttt{.cshrc} file and add

\begin{verbatim}
setenv PATH /usr/bin:/usr/local/bin:<your path>
\end{verbatim}

Then you can compile as

\begin{verbatim}
make -f <Your makefile>
\end{verbatim}

where \texttt{-f} is the \texttt{make} command option to specify a particular makefile.

For some versions of make, a default Fortran compiler macro \texttt{F77} is available. If you want to use it, you should provide the following settings in the startup file for your command shell:

- On an IA-32 system: \texttt{F77 ifc}
- On an Itanium®-based system: \texttt{F77 efc}

Input Files

The Intel\textregistered{} Fortran Compiler interprets the type of each input file by the filename extension; for example, \texttt{.a}, \texttt{.f}, \texttt{.ftn}, \texttt{.o}, and so on.

<table>
<thead>
<tr>
<th>Filename</th>
<th>Interpretation</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{filename.a}</td>
<td>object library</td>
<td>Passed to \texttt{ld}.</td>
</tr>
<tr>
<td>\texttt{filename.f}</td>
<td>Fortran source</td>
<td>Compiled by Intel\textregistered{} Fortran Compiler, assumes fixed-form source.</td>
</tr>
<tr>
<td>\texttt{filename.ftn}</td>
<td>Fortran source</td>
<td>Compiled by Intel Fortran Compiler; assumes fixed form source.</td>
</tr>
<tr>
<td>\texttt{filename.for}</td>
<td>Fortran source</td>
<td>Compiled by Intel Fortran Compiler; assumes fixed form source.</td>
</tr>
</tbody>
</table>
You can use the compiler configuration file ifc.cfg for IA-32 or efc.cfg for Itanium-based applications to specify default directories for input libraries and for work files. To specify additional directories for input files, temporary files, libraries, and for the assembler and the linker, use compiler options that specify output file and directory names.

**Default Behavior Overview**

By default, the compiler generates executable file(s) of the input file(s) and performs the following actions:

- Searches for all files, including library files, in the current directory
- Passes options designated for linking as well as user-defined libraries to the linker
- Displays error and warning messages
- Supports the extended ANSI standard for the Fortran language.
- Performs default settings and optimizations using options summarized in the Default Behavior of the Compiler Options section.
- For IA-32 applications, the compiler uses -tpp7 option to optimize the code for the Intel® Pentium® 4 and Intel® Xeon(TM) processor; for Itanium®-based applications, the compiler uses -tpp2 option to optimize the code for the Itanium® 2 processor.

For unspecified options, the compiler uses default settings or takes no action. If the compiler cannot process a command-line option, that option is passed to the linker.

**Default Behavior of the Compiler Options**

If you invoke the Intel® Fortran Compiler without specifying any compiler options, the
default state of each option takes effect. The following tables summarize the options whose
default status is ON as they are required for Intel Fortran Compiler default operation. The
tables group the options by their functionality.

Per your application requirement, you can disable one or more options.

For the default states and values of all options, see the Compiler Options Quick Reference Alphabetical table. The table provides links to the sections describing the functionality of the options. If an option has a default value, such value is indicated. If an option includes an optional minus [-], this option is ON by default.

The following tables list all options that compiler uses for its default execution.

**Data Setting and Language Conformance**

<table>
<thead>
<tr>
<th>Default Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-72</td>
<td>-72, -80, -132 specifies the column length for fixed form source only. The compiler might issue a warning for non-numeric text beyond 72 for the -72 option.</td>
</tr>
<tr>
<td>-ansi_alias[-]</td>
<td>Enables assumption of the program's ANSI conformance.</td>
</tr>
<tr>
<td>-align</td>
<td>Analyzes and reorders memory layout for variables and arrays.</td>
</tr>
<tr>
<td>-auto_scalar</td>
<td>Makes scalar local variables AUTOMATIC.</td>
</tr>
<tr>
<td>-dps</td>
<td>Enables DEC* parameter statement recognition.</td>
</tr>
<tr>
<td>-i4</td>
<td>-i{2 4 8} defines the default KIND for integer variables and constants in 2, 4, and 8 bytes.</td>
</tr>
<tr>
<td>-lowercase</td>
<td>Controls the case of routine names and external linker symbols to all lowercase characters.</td>
</tr>
<tr>
<td>-nostack_temps</td>
<td>Allocates temporary array in the heap.</td>
</tr>
<tr>
<td>-pad</td>
<td>Enables changing variable and array memory layout.</td>
</tr>
<tr>
<td>-pc80</td>
<td>-pc{32 64 80} enables floating-point significand precision control as follows: -pc32 to 24-bit significand, -pc64 to 53-bit significand, and -pc80 to 64-bit significand.</td>
</tr>
<tr>
<td>IA-32 only</td>
<td></td>
</tr>
</tbody>
</table>
### Optimizations

<table>
<thead>
<tr>
<th>Default Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-save</td>
<td>Saves all variables in static allocation. Disables -auto, that is, disables setting all variables AUTOMATIC.</td>
</tr>
<tr>
<td>-u</td>
<td>Sets IMPLICIT NONE.</td>
</tr>
<tr>
<td>-us</td>
<td>Appends an underscore to external subroutine names.</td>
</tr>
</tbody>
</table>

**IA-32:** -Zp4  
**Itanium compiler:** -Zp8  
- Zp{n} specifies alignment constraint for structures on 1-, 2-, 4-, 8-, or 16-byte boundary. To disable, use -align-.

#### Default Option

<table>
<thead>
<tr>
<th>Default Option</th>
<th>Description</th>
</tr>
</thead>
</table>
| -fp                  | IA-32 only  
Disables the use of the ebp register in optimizations. Directs to use the ebp-based stack frame for all functions. |
| -ip_no_inlining      | Disables full or partial inlining that would result from the -ip interprocedural optimizations. Requires -ip or -ipo.                       |
| -IPF_fltacc          | Itanium® compiler  
Enables the compiler to apply optimizations that affect floating-point accuracy.                                                       |
| -IPF_fma             | Itanium compiler  
Enables the contraction of floating-point multiply and add/subtract operations into a single operation.                                  |
| -IPF_fp_speculation  | fast  
Itanium compiler  
Sets the compiler to speculate on floating-point operations. -IPF_fp_speculation off disables this optimization.                       |
| -ipo_obj             | Itanium compiler  
Forces the generation of real object files. Requires -ipo. IA-32 systems: OFF                                                        |
| -O, -O1, -O2         | Optimize for maximum speed.                                                                                                                  |
| -Ob1                 | Disables inlining unless -ip or -Ob2 is specified.                                                                                           |
| -openmp_report1      | Indicates loops, regions, and sections parallelized.                                                                                         |
| -opt_report_levelmin | Specifies the minimal level of the optimizations report.                                                                                     |
Compilation

<table>
<thead>
<tr>
<th>Default Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-falias</td>
<td>Assumes aliasing in program.</td>
</tr>
<tr>
<td>-ffnalias</td>
<td>Assumes aliasing within functions.</td>
</tr>
<tr>
<td>-fverbose-asm</td>
<td>Produces assembly file with compiler comments including compiler version and options used.</td>
</tr>
<tr>
<td>-fpp1</td>
<td>When preprocessor runs, enables CVF conditional and # directives.</td>
</tr>
<tr>
<td>-sox-</td>
<td>Disables saving of compiler options and version in the executable. For Itanium-based systems, accepted for compatibility only.</td>
</tr>
</tbody>
</table>

Messages and Diagnostics

<table>
<thead>
<tr>
<th>Default Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-cerrs</td>
<td>Enables errors and warning messages to be printed in a terse format. To disable, use -cerrs-.</td>
</tr>
<tr>
<td>-d0</td>
<td>Displays only the procedure name and the number of the line at which the failure occurred.</td>
</tr>
<tr>
<td>-W1</td>
<td>Displays warnings.</td>
</tr>
</tbody>
</table>
Disabling Default Options

To disable an option, use one of the following as applies:

- Generally, to disable one or a group of optimization options, use `-O0` option. For example:

  **IA-32 applications:**
  
  `prompt>ifc -O2 -O0 input_file(s)`

  **Itanium-based applications:**
  
  `prompt>efc -O2 -O0 input_file(s)`

**Note**
The `-O0` option is part of a mutually-exclusive group of options that includes `-O0`, `-O`, `-O1`, `-O2`, and `-O3`. The last of any of these options specified on the command line will override the previous options from this group.

- To disable options that include optional "-" shown as `[ - ]`, use that version of the option in the command line, for example: `-align-`.

- To disable options that have `{n}` parameter, use `n=0` version, for example: `-unroll0`.

**Note**
If there are enabling and disabling versions of switches on the line, the last one takes precedence.

Resetting Default Data Types

To reset data type default options, you need to indicate a new option which overrides the default setting. For example:

**IA-32 applications:**

`prompt>ifc -i2 input_file(s)`

**Itanium-based applications:**

`prompt>efc -i2 input_file(s)`

Option `-i2` overrides default option `-i4`. 
Default Libraries and Tools

For the libraries provided with Intel® Fortran Compiler, see IA-32 compiler libraries list and Itanium® compiler libraries list.

The default tools are summarized in the table below.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Default</th>
<th>Provided with Intel Fortran Compiler</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA-32 Assembler</td>
<td>Linux* Assembler, as</td>
<td>No</td>
</tr>
<tr>
<td>Itanium® Assembler</td>
<td>Intel® Itanium® Assembler</td>
<td>Yes</td>
</tr>
<tr>
<td>Linker</td>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>

You can specify alternate to default tools and locations for preprocessing, compilation, assembly, and linking.

Assembler

By default, the compiler generates an object file directly without calling the assembler. However, if you need to use specific assembly input files and then link them with the rest of your project, you can use an assembler for these files.

IA-32 Applications

For 32-bit applications, Linux supplies its own assembler, as. For Itanium-based applications, to compile to assembly files and then use an assembler to produce executables, use the Itanium assembler, ias.

Itanium®-based Applications

If you need to assemble specific input files and link them to the rest of your project object files, produce object files using Intel® Itanium® assembler with ias command. For example, if you want to link some specific input file to the Fortran project object file, do the following:

1. Issue command using –S option to generate an assembly code file, file.s.
   
   ```prompt>efc -S -c file.f```

2. To assemble the file.s file, call Itanium® assembler with this command:
   
   ```prompt>ias -Nso -p32 -o file.o file.s```

where the following assembler options are used:
-Nso suppresses sign-on message

-p32 enables defining 32-bit elements as relocatable data elements. Kept for backward compatibility

-o file indicates the output object file name

The above command generates an object file, file.o, which you can link with the object file of the whole project.

**Linker**

The compiler calls the system linker, ld(1), to produce an executable file from object files. The linker searches the environment variable LD_LIBRARY_PATH to find available libraries.

**Compilation Phases**

To produce the executable file `filename`, the compiler performs by default the compile and link phases. When invoked, the compiler driver determines which compilation phases to perform based on the extension of the source filename and on the compilation options specified in the command line.

The table that follows lists the compilation phases and the software that controls each phase.

<table>
<thead>
<tr>
<th>Phases</th>
<th>Software</th>
<th>IA-32 or Itanium® Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preprocess</td>
<td>fpp</td>
<td>Both</td>
</tr>
<tr>
<td>(Optional)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compile</td>
<td>f90com</td>
<td>Both</td>
</tr>
<tr>
<td>Assemble</td>
<td>ias</td>
<td>Itanium architecture</td>
</tr>
<tr>
<td>Link</td>
<td>ld</td>
<td>Both</td>
</tr>
</tbody>
</table>

The compiler passes object files and any unrecognized filename to the linker. The linker then determines whether the file is an object file (.o) or a library (.a). The compiler driver handles all types of input files correctly, thus it can be used to invoke any phase of compilation.

**Application Development Cycle**

The relationship of the compiler to system-specific programming support tools is presented in the Application Development Cycle diagram.

The compiler processes Fortran language source and generates object files. You decide
the input and output by setting options when you run the compiler. The figure shows how the compiler fits into application development environment.
Customizing Compilation Environment

You can customize the compilation process of your Fortran programs with the Fortran Compilation Environment (FCE) included with the Intel® Fortran Compiler. FCE provides a methodology of handling compilation according to the size and structure of your program. In addition, the FCE provides a methodology for code reusability and other automated features. The modular approach also facilitates several levels of use, from short programs to complex and large-scale projects.

To customize the environment used during compilation, you can specify the variables, options, and files as follows:

- **Environment variables** to specify paths where the compiler searches for special files such as libraries and "include" files
- **Configuration files** to use the options with each compilation
- **Response files** to use the options and files for individual projects
- **Include Files** to use for your application

Environment Variables

There are a number of environment variables that control the compiler’s behavior. These environment variables can be set in the startup file for your command shell, or your `.login` file. Alternatively, you can invoke the setting variables script before running the compiler.

You can also set the `PATH` and `LD_LIBRARY_PATH` in your `.login` file only, there will no longer be any need to execute the setting variables script before running the compiler.

The following variables are relevant to your compilation environment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EFCCFG</strong></td>
<td>Specifies the configuration file that the compiler should use instead of the default configuration file for the Itanium® compiler.</td>
</tr>
<tr>
<td><strong>IFCCFG</strong></td>
<td>Specifies the configuration file that the compiler should use instead of the default configuration file for the IA-32 compiler.</td>
</tr>
<tr>
<td><strong>F_UFMTENDIAN</strong></td>
<td>Specifies the numbers of the units to be used for little-endian-to-big-endian conversion purposes.</td>
</tr>
</tbody>
</table>
IFCCFG and EFCCFG environment variables specify the configuration file that the compiler should use instead of the default configuration file. The default configuration files are *ifc.cfg* for the 32-bit Intel Fortran compiler and *efc.cfg* for the Itanium compiler in the */bin* directory, and by default, the compiler always picks up the *.cfg* file from the same directory where the compiler executable resides. However, if the user needs to use a configuration file in a different location, they can use the IFCCFG or EFCCFG environment variable and assign the directory and filename of the *.cfg* file that needs to be picked up by the compiler.

### Configuration Files

To decrease the time when entering command line options and ensure consistency of often-used command-line entries, use the configuration files. You can insert any valid command-line options into the configuration file. The compiler processes options in the configuration file in the order they appear followed by the command-line options that you specify when you invoke the compiler.

```markdown
Note

Be aware that options placed in the configuration file will be included each time you run the compiler. If you have varying option requirements for different projects, see Response Files.

These files can be added to the directory where Intel® Fortran Compiler is installed.

Examples that follow illustrate sample *.cfg* files. The pound (#) character indicates that the rest of the line is a comment.
IA-32 applications: ifc.cfg

You can put any valid command-line option into this file.

```plaintext
### Sample ifc.cfg file for IA-32 applications
### Define preprocessor macro
MY_PROJECT.
-Dmy_project
### Set extended-length source lines.
-132
### Set maximum floating-point significand precision.
-PC80
### Link with alternate I/O library for mixed output with the
### C language.
-C90
```

Itanium®-based applications: efc.cfg

```plaintext
### Sample efc.cfg file for Itanium®-based applications
### Define preprocessor macro
MY_PROJECT.
-Dmy_project
### Enable extended-length source lines.
-132
### Link with alternate I/O library for mixed output with the
### C language.
-C90
```

Response Files

Use response files to specify options used during particular compilations for particular projects, and to save this information in individual files. Response files are invoked as an option on the command line. Options specified in a response file are inserted in the
command line at the point where the response file is invoked.

Response files are used to decrease the time spent entering command-line options, and to ensure consistency by automating command-line entries. Use individual response files to maintain options for specific projects; in this way you avoid editing the configuration file when changing projects.

You can place any number of options or filenames on a line in the response file. Several response files can be referenced in the same command line.

The syntax for using response files is as follows:

**IA-32 applications:**

```plaintext
prompt> ifc @response_filename

prompt> ifc @response_filename1 @response_filename2
```

**Itanium®-based applications:**

```plaintext
prompt> efc @response_filename

prompt> efc @response_filename1 @response_filename2
```

⚠️ **Note**

An "at" sign (@) must precede the name of the response file on the command line.

## Include Files

Include files are brought into the program with the `#include` preprocessor directive or the `INCLUDE` statement. In addition, you can define a specific location of include files with the compiler options, `-I dir` and `-X`. See [Searching for Include Files](#) in Preprocessing.
Customizing Compilation Process

This section describes options that customize compilation process—preprocessing, compiling, and linking. In addition, it discusses various compilation output and debug options and also shows how little-endian-to-big-endian conversions are enabled for unformatted sequential files.

You can find information on the link-time libraries used by compiler, compiler diagnostics, and mixing C and Fortran in the corresponding sections.

Specifying Alternate Tools and Locations

The Intel® Fortran Compiler lets you specify alternate to default tools and locations for preprocessing, compilation, assembly, and linking. Further, you can invoke options specific to your alternate tools on the command line. This functionality is provided by –Qlocation and –Qoption.

Specifying an Alternate Component
(–Qlocation, tool, path)

–Qlocation enables to specify the pathname locations of supporting tools such as the assembler, linker, preprocessor, and compiler. This option’s syntax is:

–Qlocation, tool, path

<table>
<thead>
<tr>
<th>tool</th>
<th>Designates one or more of these tools:</th>
</tr>
</thead>
<tbody>
<tr>
<td>fpp</td>
<td>Intel Fortran preprocessor</td>
</tr>
<tr>
<td>f</td>
<td>Fortran compiler</td>
</tr>
<tr>
<td>(f90com)</td>
<td></td>
</tr>
<tr>
<td>asm</td>
<td>IA-32 assembler</td>
</tr>
<tr>
<td>ias</td>
<td>Itanium® assembler</td>
</tr>
<tr>
<td>link</td>
<td>Linker (ld(1))</td>
</tr>
</tbody>
</table>

| path | The location of the component. |

Example:

prompt> ifc –Qlocation, fpp, /usr/preproc myprog.f

Passing Options to Other Tools (–Qoption, tool, opts)

–Qoption passes an option specified by opts to tool, where opts is a comma-separated list of options. The syntax for this option is:
-Qoption, tool, opts

<table>
<thead>
<tr>
<th>tool</th>
<th>Designates one or more of these tools:</th>
</tr>
</thead>
<tbody>
<tr>
<td>fpp</td>
<td>Intel Fortran preprocessor</td>
</tr>
<tr>
<td>f</td>
<td>Fortran compiler</td>
</tr>
<tr>
<td>(f90com)</td>
<td></td>
</tr>
<tr>
<td>link</td>
<td>Linker (ld (1))</td>
</tr>
</tbody>
</table>

| opts   | Indicates one or more valid argument strings for the designated program. |

If the argument contains a space or tab character, you must enclose the entire argument in quotation characters (" "). You must separate multiple arguments with commas including those in quotation marks.

The following example directs the linker to link with alternate I/O library for mixed output with the C language for respective targeted compilations.

**IA-32 applications:**

```
prompt> ifc -Qoption, link, -C90 prog1.f
```

**Itanium®-based applications:**

```
prompt> efc -Qoption, link, -C90 prog1.f
```

## Preprocessin

This section describes the options you can use to direct the operations of the preprocessor. Preprocessing performs such tasks as macro substitution, conditional compilation, and file inclusion. You can use the preprocessor options to direct the operations of the preprocessor from the command line. The compiler preprocesses files as an optional first phase of the compilation.

The Intel® Fortran Compiler provides the fpp binary to enable preprocessing. If you want to use another preprocessor, you must invoke it before you invoke the compiler. Source files that use a .fpp or .F file extension are automatically preprocessed.

⚠️ **Caution**

Using a preprocessor that does not support Fortran can damage your Fortran code, especially with FORMAT statements. For example, `FORMAT ("I4")` changes the meaning of the program because the backslash "\" indicates end-of-record.

## Preprocessor Options
Use the options in this section to control preprocessing from the command line. If you specify neither option, the preprocessed source files are not saved but are passed directly to the compiler. Table that follows provides a summary of the available preprocessing options.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-A[-]</td>
<td>Removes all predefined macros.</td>
</tr>
<tr>
<td>-Dname={#</td>
<td>text}</td>
</tr>
<tr>
<td>-E</td>
<td>Directs the preprocessor to expand your source module and write the result to standard output.</td>
</tr>
<tr>
<td>-EP</td>
<td>Same as -E but does not include #line directives in the output.</td>
</tr>
<tr>
<td>-F</td>
<td>Preprocess to an indicated file.</td>
</tr>
<tr>
<td>-fpp{n}</td>
<td>Uses the fpp preprocessor on Fortran source files.</td>
</tr>
<tr>
<td></td>
<td>n=0: disable CVF and #directives n=1: enable CVF conditional compilation and #directives (default)</td>
</tr>
<tr>
<td></td>
<td>n=2: enable only #directives, n=3: enable only CVF conditional compilation directives.</td>
</tr>
<tr>
<td>-P</td>
<td>Directs the preprocessor to expand your source module and store the result in a file in the current directory.</td>
</tr>
<tr>
<td>-Uname</td>
<td>Eliminates any definition currently in effect for the specified macro.</td>
</tr>
<tr>
<td>-Idir</td>
<td>Adds directory to the include file search path.</td>
</tr>
<tr>
<td>-X</td>
<td>Removes standard directories from the include file search path.</td>
</tr>
</tbody>
</table>

### Preprocessing Fortran Files

You do not usually preprocess Fortran source programs. If, however, you choose to preprocess your source programs, you must use the preprocessor fpp, or the preprocessing capability of a Fortran compiler. It is recommended to use fpp, which is the preprocessor supplied with the Intel® Fortran Compiler.

The compiler driver automatically invokes the preprocessor, depending on the source filename suffix and the option specified. For example, to preprocess a source file that contains standard Fortran preprocessor directives, then pass the preprocessed file to the compiler and linker, enter the following command:

**IA-32 applications:**
prompt> ifc source.fpp/source.F90

Itanium®-based applications:

prompt> efc source.fpp/source.F90

The .fpp or .F90 file extension invokes the preprocessor. Note the capital F in the file extension to produce the effect.

Note
Using the preprocessor can make debugging difficult. To get around this, you can save the preprocessed file (-P), and compile it separately, so that the proper file information is recorded for the debugger.

Enabling Preprocessing with CVF

You can enable the Preprocessor for any Fortran file by specifying the -fpp option. With -fpp, the compiler automatically invokes the fpp (preprocessor) to preprocess files with the .f, .ftn, .for or .f90 extension in the mode set by n:

n=0: disable CVF and #directives
n=1: enable CVF conditional compilation and #directives; -fpp1 is the default when the preprocessor is invoked.

n=2: enable only #directives
n=3: enable only CVF conditional compilation directives.

Note
Option -openmp automatically invokes the preprocessor.

String Constants for IA-32 Systems

Intel Fortran fpp conforms to cpp and accepts the cpp style directives. cpp prohibits the use of a string constant value in #if expression. So fpp won't support it either.

```fortran
#define system "ia32"
#if system == "ia32"
    void main() {
        printf("ia32\n");
    }
#else
    int main() {
```
Preprocessing Only: -E, -EP, -F, and -P

Use either the -E, -P, or the -F option to preprocess your .fpp source files without compiling them.

When you specify the -E option, the Intel® Fortran Compiler's preprocessor expands your source file and writes the result to standard output. The preprocessed source contains #line directives, which the compiler uses to determine the source file and line number during its next pass. For example, to preprocess two source files and write them to stdout, enter the following command:

**IA-32 applications:**

```
prompt>ifc -E prog1.fpp prog2.fpp
```

**Itanium®-based applications:**

```
prompt>efc -E prog1.fpp prog2.fpp
```

When you specify the -P option, the preprocessor expands your source file and stores the result in a file in the current directory. By default, the preprocessor uses the name of each source file with the .f extension, and there is no way to change the default name. For example, the following command creates two files named prog1.f and prog2.f, which you can use as input to another compilation:

**IA-32 applications:**

```
prompt>ifc -P prog1.fpp prog2.fpp
```

**Itanium-based applications:**

```
prompt>efc -P prog1.fpp prog2.fpp
```

The -EP option can be used in combination with -E or -P. It directs the preprocessor to not include #line directives in the output. Specifying -EP alone is the same as specifying -E and -EP.

⚠️ Caution

When you use the -P option, any existing files with the same name and extension are not overwritten and the system returns the error message invalid preprocessor output file.
Fortran Programs with Modules

A module is a type of program unit that contains specifications of such entities as data objects, parameters, structures, procedures, and operators. These specifications and definitions can be used by one or more program units. Partial or complete access to the module entities is provided by the `USE` statement. Typical applications of modules are the specification of global data or the specification of a derived type and its associated operations.

For detailed information about Fortran modules, refer to Chapter 7 in the *Intel® Fortran Programmer’s Reference*.

The programs in which modules are defined support such compilation mechanisms as parallel invocations with make files for **Inter-procedural optimizations** of multiple files and of the whole program. The programs that require modules located in multiple directories, can be compiled using the `-Idir` option to locate the `.mod` files (modules) that should be included in the program.

⚠️ **Note**

The current version of the Intel® Fortran Compiler does not support VAX STRUCTURES within the Fortran modules.

Specifying the `.mod` Files Location

With the `-module[path]` option, you can specify the directory where you need to store the `.mod` files. The option has the following versions:

<table>
<thead>
<tr>
<th><code>-modulepath</code></th>
<th>The <code>path</code> specifies the directory to rout the module files to.</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-module</code></td>
<td>The module files are placed in the same directory as the object files. Should a path be specified with the <code>-object</code> option, that location would also be used for the <code>.mod</code> files.</td>
</tr>
<tr>
<td><code>-nomodule</code></td>
<td>The module files are placed in the same directory where the source files are being compiled.</td>
</tr>
</tbody>
</table>

You need to ensure that the module files are created before they are referenced by another program or subprogram.

Compiling Programs with Modules

If a file being compiled has one or more modules defined in it, the compiler generates one or more `.mod` files. For example, a file `a.f90` contains modules defined as follows:
The compile command:

`prompt>ifc -c a.f90`

generates the following three files:

- `a.o`
- `TEST.mod`
- `FOOBAR.mod`

**Note**

The names of the `.mod` files are in uppercase; the name of the program file is not changed in the object file.

The `.mod` files contain the necessary information regarding the modules that have been defined in the program `a.f90`.

If the program does not contain a module, no `.mod` file is generated. For example, `test2.f90` does not contain any modules. The compile command:

`prompt>ifc -c test2.f90`

produces just an object file, `test2.o`.

**Working with Multimodule Programs**

By default, the `ifc` (IA-32 compiler) or `efc` (Itanium® compiler) command compiles each program unit for multimodule usage in the FCE. There are two ways (described below) of working with multimodule programs depending on the scale of your project.

**Small-Scale Projects**

```fortran
module test
    integer:: a
    contains
    subroutine foo()
    end subroutine
end module

module foobar
    :
    :
end module
```
In a small-scale project, the source files are in a single directory, so module management is not an issue. A simple way to compile and use modules is to incorporate a module before a program unit that references it with *USE*. In this case, sources may be compiled and linked in the same way as FORTRAN 77 sources; for example if file1.f90 contains one or more modules and file2.f90 contains one or more program units that call these modules with the *USE* statement. The sources may be compiled and linked by the commands:

**IA-32 applications:**

```bash
prompt>ifc file1.f90 file2.f90
```
or

```bash
prompt>ifc -c file1.f90 (where the -c option stops the compilation after an .o file has been created)
```

```bash
prompt>ifc file1.o file2.f90
```

**Itanium®-based applications:**

Use *efl* instead of *ifl* command, the rest is the same.

**Searching and Locating the .mod Files in Large-Scale Projects**

To manage modules in a large-scale software project, when the *mod* files could be produced in different directories, the Intel® Fortran Compiler uses the *-Idir* option to specify the location of the *mod* files. For example, your program mod_def.f90 resides in directory /usr/yourdir/test/t, and this program contains a module defined as follows:

```
file:
mod_def.f90
module
definedmod
:
:
end module
```

The compile command:

```bash
prompt>ifc -c mod_def.f90
```

produces two files: *mod_def.o* and *DEFINEDMOD.mod* in directory /usr/yourdir/test/t.

If you need to use the above *.mod* file in another directory, for example, in directory /usr/yourdir/test/t2, where the program *foo* needs to use the *DEFINEDMOD.mod* file, implement the *use* statement as follows:
To compile the above program, issue command:

```
prompt> ifc -c use_mod_def.f90 -l/usr/yourdir/test/t
```

where the -ldir option provides the compiler with the path to search and locate the DEFINEDMOD.mod file.

**Parallel Invocations with Makefile**

The programs in which modules are defined, support the compilation mechanisms, such as parallel invocations with makefile for inter-procedural optimizations of multiple files. Consider the following code.

```fortran
file:
use_mod_def.f90
program foo
use DEFINEDMOD
::
end program
```

To compile the above program, issue command:

```
prompt> ifc -c use_mod_def.f90 -l/usr/yourdir/test/t
```

where the -ldir option provides the compiler with the path to search and locate the DEFINEDMOD.mod file.

**Parallel Invocations with Makefile**

The programs in which modules are defined, support the compilation mechanisms, such as parallel invocations with makefile for inter-procedural optimizations of multiple files. Consider the following code.

```fortran
test1.f90
module foo
::
end module

test2.f90
subroutine bar()
use foo
::
end subroutine

test3.f90
subroutine foobar()
use foo
::
end subroutine
```

The makefile to compile the above code looks like this:
Searching for Include and .mod Files

Include files are brought into the program with the `#include` preprocessor directive or the `INCLUDE` statement. To locate such included files, the compiler searches by default for the standard include files in the directories specified in the `INCLUDE` environment variable. In addition, you can specify the compiler options, `-I` and `-X`.

**Specifying and Removing Include Directory Search: –I, –X**

You can use the `–I` option to indicate the location of include files and .mod files. To prevent the compiler from searching the default path specified by the `INCLUDE` environment variable, use `–X` option.

You can specify these options in the configuration files, `ifc.cfg` for IA-32 or `efc.cfg` for Itanium®-based applications or on the command line.

**Specifying an Include Directory, –Idir**

Included files are brought into the program with a `#include` preprocessor directive or a Fortran `INCLUDE` statement. Use the `–Idir` option to specify an alternative directory to search for include files.

Files included by the Fortran `INCLUDE` statement are normally referenced in the same directory as the file being compiled. The `–I` option may be used more than once to extend the search for an `INCLUDE` file into other directories.

Directories are searched for include files in this order:

- directory of the source file that contains the include
- directories specified by the `–I` option
- current working directory
- directories specified with the `INCLUDE` environment variable

**Compiling an Input File from a Different Directory**

```plaintext
FOO.mod: test1.o
test1.o:
  ifc -c test1.f90
test2.o: FOO.mod
  ifc -c test2.f90
test3.o: FOO.mod
  ifc -c test3.f90
```
If you need to compile an input file that resides in a directory other than default (that is, the directory where you issue a compilation command) and if your code contains an INCLUDE statement, you must use the -I dir option on your command line. For example:

**IA-32 applications:**

```
prompt> ifc -I dir dir/file.f90
```

**Itanium®-based applications:**

```
prompt> efc -I dir dir/file.f90
```

where *dir* is the directory path where the file, *file.f90*, you need to compile resides.

### Specifying the .mod Files Directory

The programs that require modules located in multiple directories can be compiled using the -I dir option to locate the .mod files (modules) that should be included in the program. For specifying the directory to locate .mod files, see Searching and Locating the .mod Files in Large-Scale Projects.

### Removing Include Directories, -x

Use the -X option to prevent the compiler from searching the default path specified by the INCLUDE environment variable.

You can use the -X option with the -I option to prevent the compiler from searching the default path for include files and direct it to use an alternate path. For example, to direct the compiler to search the path /alt/include instead of the default path, do the following:

**IA-32 applications:**

```
prompt> ifc -X -I/alt/include newmain.f
```

**Itanium-based applications:**

```
prompt> efc -X -I/alt/include newmain.f
```

### Defining Macros

You can use the /D option to define the assertion and macro names to be used during preprocessing. The -U name option disable macros.

Use the -D option to define a macro. This option performs the same function as the #define preprocessor directive. The format of this option is:
-Dname[=value{text}]

where

<table>
<thead>
<tr>
<th>name</th>
<th>The name of the macro to define.</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td>Indicates a value to be substituted for name.</td>
</tr>
</tbody>
</table>

If you do not enter a value, name is set to 1. The value should be enclosed in the quotation marks if it contains spaces or special characters.

Preprocessing replaces every occurrence of name with the specified value. For example, to define a macro called SIZE with the value 100 use the following command:

**IA-32 applications:** `prompt>ifc -DSIZE=100 prog1.f`

**Itanium®-based applications:** `prompt>efc -DSIZE=100 prog1.f`

Preprocessing replaces all occurrences of SIZE with the specified value before passing the preprocessed source code to the compiler. Suppose the program contains the declaration:

```
REAL Vector(SIZE)
```

In the code sent to the compiler, the value 100 replaces SIZE in this declaration, and in every other occurrence of the name SIZE.

### Predefined Macros

The predefined macros available for the Intel® Fortran Compiler are described in the table below. The Default column describes whether the macro is enabled (ON) or disabled (OFF) by default. The Disable column lists the option which disables the macro.

<table>
<thead>
<tr>
<th>Macro Name</th>
<th>Default</th>
<th>Architecture</th>
<th>Description - When Used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EFC</strong></td>
<td>ON</td>
<td>Itanium</td>
<td>Identifies the Intel Fortran Compiler</td>
</tr>
<tr>
<td><strong>IFC</strong></td>
<td>ON</td>
<td>IA-32</td>
<td>Identifies the Intel Fortran Compiler</td>
</tr>
<tr>
<td><strong>linux</strong></td>
<td>ON</td>
<td>IA-32</td>
<td>Defined for Linux* applications</td>
</tr>
<tr>
<td><em>M_IA64_linux</em>_</td>
<td>ON</td>
<td>Itanium®</td>
<td>Defined for Itanium-based Linux applications</td>
</tr>
</tbody>
</table>
Suppressing Macros

The `-U` option directs the preprocessor to suppress an automatic definition of a macro. Use the `-Uname` option to suppress any macro definition currently in effect for the specified `name`. The `-U` option performs the same function as an `#undef` preprocessor directive.

Preprocessor Macro for OpenMP*

A preprocessor macro is defined which may be useful for running OpenMP* depending on the compiler environment:

`_OPENMP`

This macro has the form YYYYMM where YYYY is the year and MM is the month of the OpenMP Fortran specification supported.

Compilation

This section describes all the Intel® Fortran Compiler options that determine the compilation and linking process and their output. By default, the compiler converts source code directly to an executable file. Appropriate options enable you to control the process and obtain desired output file produced by the compiler.

Having control of the compilation process means, for example, that you can create a file at any of the compilation phases such as assembly, object, or executable with `-P` or `-c` options. Or you can name the output file or designate a set of options that are passed to the linker with the `-S`, `-o` options. If you specify a phase-limiting option, the compiler produces a separate output file representing the output of the last phase that completes for each primary input file.

You can use the command line options to display and check for certain aspects of the compiler's behavior. You can use these options to see which options and files are passed by the compiler driver to the component executables `f90com` and `ld(1)` (option `-sox [l-1]).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Defined based on the processor option you specify:</th>
</tr>
</thead>
<tbody>
<tr>
<td>_M_IX86=n</td>
<td>ON, n=700</td>
<td>IA-32</td>
<td><code>n=500</code> if you specify <code>-tpp5</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><code>n=600</code> if you specify <code>-tpp6</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><code>n=700</code> if you specify <code>-tpp7</code></td>
</tr>
<tr>
<td>_PGO_INSTRUMENT</td>
<td>OFF</td>
<td>Both</td>
<td>Defined when you compile with <code>-prof_gen</code> options.</td>
</tr>
</tbody>
</table>

---

*Note: OpenMP is a parallel programming specification for shared-memory parallelism.
Linking is the last phase in the compilation process discussed in a separate section. See the [Linking options](#).

A group of options monitors the outcome of Intel compiler-generated code without interfering with the way your program runs. These options control some computation aspects, such as allocating the stack memory, setting or modifying variable settings, and defining the use of some registers.

The options in this section provide you with the following capabilities:

- GCC* compatibility
- controlling compilation
- monitoring data settings
- specifying the output files or directories

Finally, the output options are summarized in [Compiler Output Options Summary](#).

**Controlling Compilation**

You can control and modify the compilation process with the option sets as follows.

**Controlling Compilation Phases**

You can control which compilation phases you need to include in the compilation process.

- The `-c` option directs the compiler to compile, assemble and generate object file(s), but do not link.
- The `-S` option stops compiler at generating assembly files.
- If you need to link additional files and/or libraries, you use the `-lname` option. For example, if you want to link `libm.a`, the command is:

  **IA-32 compiler:**

  `prompt>ifc a.f -lm`

  **Itanium® compiler:**

  `prompt>efc a.f -lm`

**Aliasing**
The following options manage compiler aliasing:

- **-falias** assumes aliasing in a program
- **-fno-alias** assumes no aliasing in a program
- **-ffnalias** assumes aliasing within functions
- **-fno-fnalias** assumes no aliasing within functions, but assumes aliasing across calls

### Translating Other Code to Fortran

The `/Tffile` option enables you to treat a text file as if it contains Fortran code. This option is used if you have a Fortran file that has other than the `.f/.for/.f90` extension or no extension, and you need to compile it.

For example:

```
prompt> ifc -Tfa.f95 b.f
```

The above command will compile both `a.f95` and `b.f` files as Fortran, link them, and create executable `a`.

### Profiling Support

Profiling information identifies those parts of your program where improving source code efficiency would most likely improve runtime performance.

The options supporting profiling are `-p` and `-qp`, and `-pg` ( `-pg` is used for IA-32 only). `-p` and `-qp` set up profiling by periodically sampling the value of the program counter for use with the postprocessor `prof` tool.

These options only affect loading. When loading occurs, these options replace the standard runtime startup routine option with the profiling runtime startup routine. When profiling occurs, an output file is produced, which contains execution-profiling data for use with the postprocessor `prof` command.

- `-pg` (IA-32 only) sets up profiling for `gprof` tool, which produces a call graph showing the execution of the program. When programs are linked with the `-pg` option and then run, these files produced:
  - a file containing a dynamic call graph and profile.
  - a file containing a summarized dynamic call graph and profile.
To display the output, run `gprof` on the file containing a dynamic call graph and profile.

**Saving Compiler Version and Options Information, `-sox [-]`**

You can save the compiler version and options information in the executable with `-sox`. The size of the executable on disk is increased slightly by the inclusion of these information strings. The default is `-sox-`.

The `-sox` option forces the compiler to embed in each object file a string that contains information on the compiler version and compilation options for each source file that has been compiled. When you link the object files into an executable file, the linker places each of the information strings into the header of the executable. It is then possible to use a tool, such as a strings utility, to determine what options were used to build the executable file.

⚠️ **Note**

For Itanium®-based applications, the `-sox` option is accepted for compatibility, but it does not have any effect.

**Allocating Temporary Arrays, `-[no]stack_temps`**

When the Fortran compiler has to create a temporary array, it can either allocate it in the heap or on the runtime stack with the `-[no]stack_temps` option. The `-nostack_temps` option tells the compiler to allocate temporary arrays in the heap. This is the default.

The `-stack_temps` tells the compiler to allocate such temporary arrays on the stack whenever possible. When `-stack_temps` is specified, it can happen that the program may require a larger stack than the default maximum stack size. In such case, it is possible to specify the stack size with the `limit stacksize` C-shell command or the `ulimit -s` Bourne-shell command.

The `-[no]stack_temps` option is helpful for the threaded programs such as OpenMP programs, which repeatedly allocate heap memory. Sometimes these programs degrade their performance as the number of threads increases. Allocating arrays on the stack using `-stack_temps` can eliminate such performance problems. Threaded programs using auto-parallelization or OpenMP may also need to increase the thread stack size by using `KMP_STACKSIZE` environment variable in addition to the increase in the program stack size mentioned above.

**Monitoring Data Settings**

The options described below provide monitoring the outcome of Intel compiler-generated code without interfering with the way your program runs.
Specifying Structure Tag Alignments

Use the -Zp{n} option to determine the alignment constraint for structure declarations, on n-byte boundary (n = 1, 2, 4, 8, 16). Generally, smaller constraints result in smaller data sections while larger constraints support faster execution.

For example, to specify 2 bytes as the alignment constraint for all structures and unions in the file prog1.f, use the following command:

**IA-32 systems:** prompt> ifc -Zp2 prog1.f
The default for IA-32 systems is -Zp4.

**Itanium®-based systems:** prompt> efc -Zp2 prog1.f
The default for Itanium-based systems is -Zp8.

The -Zp16 option enables you to align Fortran structures such as common blocks. For Fortran structures, see STRUCTURE statement in Chapter 10 of *Intel® Fortran Programmer's Language Reference Manual*.

The -align option applies mainly to structures and analyzes and reorders memory layout for variables and arrays and basically functions as -Zp{n}. You can disable either option with -noalign.

The -pad option is effectively not different from -align when applied to structures and derived types. However, the scope of -pad is greater because it applies also to common blocks, derived types, sequence types, and Vax structures.

Allocation of Zero-initialized Variables, -nobss_init

By default, variables explicitly initialized with zeros are placed in the BSS section. But using the -nobss_init option, you can place any variables that are explicitly initialized with zeros in the DATA section if required.

Monitoring Data for IA-32 Systems

Correcting Computations for IA-32 Processors, -0f_check

Specify the -0f_check option to avoid the incorrect decoding of the instructions that have 2-byte opcodes with the first byte containing 0f. In rare cases, the Pentium® processor can decode these instructions incorrectly.

The ebp Register Usage

The -fp option disables the use of the ebp register in optimizations. The option directs to
use the ebp-based stack frame for all functions. For details on the correlation between the ebp register use for optimizations and debugging, see -fp Option and Debugging. The -fp option is disabled by default or when -O1 or -O2 (see optimization-level options) are specified.

Little-endian-to-Big-endian Conversion (IA-32)

The Intel Fortran Compiler writes unformatted sequential files in big-endian format and reads files produced in big-endian format.

The little-endian-to-big-endian conversion feature is intended for Fortran unformatted input/output operations in unformatted sequential files. It enables the development and processing of files with big-endian data organization on the IA-32-based processors, which usually process the data in the little endian format.

The feature also enables processing of the files developed on processors that accept big-endian data format and producing the files for such processors on IA-32-based little-endian systems.

The little-endian-to-big-endian conversion is accomplished by the following operations:

- The WRITE operation converts little endian format to big endian format.
- The READ operation converts big endian format to little endian format.

The feature enables the conversion of variables and arrays (or array subscripts) of basic data types. Derived data types are not supported.

Little-to-Big Endian Conversion Environment Variable

In order to use the little-endian-to-big-endian conversion feature, specify the numbers of the units to be used for conversion purposes by setting the F_UFMTENDIAN environment variable. Then, the READ/WRITE statements that use these unit numbers, will perform relevant conversions. Other READ/WRITE statements will work in the usual way.

In the general case, the variable consists of two parts divided by a semicolon. No spaces are allowed inside the F_UFMTENDIAN value. The variable has the following syntax:

F_UFMTENDIAN=MODE | [MODE;] EXCEPTION

where:

MODE = big | little
EXCEPTION = big:ULIST | little:ULIST | ULIST
ULIST = U | ULIST,U
U = decimal | decimal - decimal

- **MODE** defines current format of data, represented in the files; it can be omitted. The keyword *little* means that the data have little endian format and will not be converted. For IA-32 systems, this keyword is a default. The keyword *big* means that the data have big endian format and will be converted. This keyword may be omitted together with the colon.

- **EXCEPTION** is intended to define the list of exclusions for **MODE**; it can be omitted. **EXCEPTION** keyword (*little* or *big*) defines data format in the files that are connected to the units from the **EXCEPTION** list. This value overrides **MODE** value for the units listed.

- Each list member U is a simple unit number or a number of units. The number of list members is limited to 64. decimal is a non-negative decimal number less than $2^{32}$.

Converted data should have basic data types, or arrays of basic data types. Derived data types are disabled.

**Command lines** for variable setting with different shells:

Sh: `export F_UFMTENDIAN=MODE;EXCEPTION`

Csh: `setenv F_UFMTENDIAN MODE;EXCEPTION`

---

**Note**

Environment variable value should be enclosed in quotes if semicolon is present.

**Another Possible Environment Variable Setting**

The environment variable can also have the following syntax:

`F_UFMTENDIAN=u[,u]` ...

**Command lines** for the variable setting with different shells:

- Sh: `export F_UFMTENDIAN=u[,u]` ...

- Csh: `setenv F_UFMTENDIAN u[,u]` ...

See **error messages** that may be issued during the little endian – big endian conversion. They are all fatal. You should contact Intel if such errors occur.

**Usage Examples**

1. `F_UFMTENDIAN=big`
All input/output operations perform conversion from big-endian to little-endian on READ and from little-endian to big-endian on WRITE.

2. \texttt{F\_UFMTENDIAN=\textquoteleft little;big:10,20\textquoteright} or \texttt{F\_UFMTENDIAN=big:10,20} or \texttt{F\_UFMTENDIAN=10,20}

   In this case, only on unit numbers 10 and 20 the input/output operations perform big-little endian conversion.

3. \texttt{F\_UFMTENDIAN=\textquoteleft big;little:8\textquoteright}

   In this case, on unit number 8 no conversion operation occurs. On all other units, the input/output operations perform big-little endian conversion.

4. \texttt{F\_UFMTENDIAN=10-20}

   Define 10, 11, 12 ... 19, 20 units for conversion purposes; on these units, the input/output operations perform big-little endian conversion.

5. Assume you set \texttt{F\_UFMTENDIAN=10,100} and run the following program.

```fortran
integer*4 cc4
integer*8 cc8
integer*4 c4
integer*8 c8

c4 = 456

C prepare a little endian representation of data
open (11,file='lit.tmp',form='unformatted')
write(11) c8
write(11) c4
close(11)

C prepare a big endian representation of data
open (10,file='big.tmp',form='unformatted')
write(10) c8
write(10) c4
close(10)
```
Now compare `lit.tmp` and `big.tmp` files with the help of `od` utility.

```
> od -t x4 lit.tmp

0000000 00000008 00000315 00000000 00000008
0000020 00000004 00001c8 00000004
0000034

> od -t x4 big.tmp

0000000 08000000 00000000 15030000 08000000
0000020 04000000 c8010000 04000000
0000034
```

You can see that the byte order is different in these files.

### Specifying Compilation Output

When compiling and linking a set of source files, you can use the `-c` or `-S` option to give the resulting file a name other than that of the first source or object file on the command line.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-c</code></td>
<td>Compile to object only (<code>.o</code>), do not link.</td>
</tr>
<tr>
<td><code>-S</code></td>
<td>Produce assembly file or directory for multiple assembly files. The compilation stops at producing the assembly file.</td>
</tr>
</tbody>
</table>
If you are processing a single file, you can use the `-ofile` option to specify an alternate name for an object file (.o), an assembly file (.s) or an executable file. You can also use these options to override the default filename extensions: .o and .s.

See [Compilation Output](#) options summary.

**Default Output Files**

The default command line does not include any options and has a Fortran source file as its input argument:

**IA-32 compiler:**

```
prompt> ifc  a.f90
```

**Itanium® compiler:**

```
prompt> efc  a.f90
```

The default compiler command produces an `a.out` executable file. If the `-c` option was used, the compiler command also produces an object file, `a.o`, and places it in the current directory.

You can compile more than one input files:

**IA-32 compiler:**

```
prompt> ifc  x.f90  y.f90  z.f90
```

**Itanium compiler:**

```
prompt> efc  x.f90  y.f90  z.f90
```

The above command will do the following:

- compile and link three input source files
- produce three object files and assign the names of the respective source files: `x.o`, `y.o`, and `z.o`
• produce an executable file and assign to it the default name a.out

• place all the files in the current directory.

To generate assembly files, use the \(-S\) option. The compilation stops at producing the assembly file.

**Specifying Executable Files**

You can use the \(-o file\) option to specify an alternate name for an executable file. This is especially useful when compiling and linking a set of input files. You can use the \(-o file\) option to give the resulting file a name other than that of the first input file (source or object) on the command line.

In the next example, the command produces an executable file named outfile as a result of compiling and linking two source files.

**IA-32 compiler:**

```bash
prompt> ifc -o outfile file1.f90 file2.f90
```

**Itanium® compiler:**

```bash
prompt> efc -o outfile file1.f90 file2.f90
```

Without the \(-o outfile\) option, the command above produces an executable file named a.out, the default executable file name.

**Specifying Object Files**

The compiler command always generates and keeps object files of the input source files and by default places them in the current directory. You can use the \(-o file\) options to specify an alternate name for an object file.

For example:

**IA-32 compiler:**

```bash
prompt> ifc -o file.o x.f90
```

**Itanium® compiler:**

```bash
prompt> efc -o file.o x.f90
```

In the above example, \(-o\) assigns the name file.o to an output object file rather than
the default \texttt{x.o}.

To generate object files, specify a different object file name, and suppress linking, use \texttt{-c} and \texttt{-o} combination.

**IA-32 applications:**

\texttt{prompt>ifc -c -o file.o x.f90}

**Itanium compiler:**

\texttt{prompt>efc -c -o file.o x.f90}

\texttt{-o} assigns the name \texttt{file.o} to an output object file rather than the default (\texttt{x.o})

\texttt{-c} directs the compiler to suppress linking.

**Specifying Assembly Files**

You can use the \texttt{-S} option to generate an assembly file. The compilation stops at producing the assembly file. To specify an alternate name for this assembly file, use the \texttt{-o file} option.

**IA-32 compiler:**

\texttt{prompt>ifc -S -o file.s x.f90}

**Itanium® compiler:**

\texttt{prompt>efc -S -o file.s x.f90}

In the above example, \texttt{-S} tells the compiler to generate an assembly file, while \texttt{-o file.s} assigns to it the name \texttt{file.s} rather than the default \texttt{x.s}.

The option \texttt{-S} tells compiler to:

- generate an assembly file of the source file
- use the name of the source file as a default assembly output file name
- place this file in the current directory.

\begin{itemize}
\item generate an assembly file of the source file
\item use the name of the source file as a default assembly output file name
\item place this file in the current directory.
\end{itemize}

\textbf{Note}

The \texttt{-S} option stops the compiler upon generating and saving the assembly files. Without the \texttt{-S} option, the compiler proceeds to generating object files without saving the assembly files.
Producing Assembly Files with Annotations and Comments

Options `-fcode-asm` and `-fsource-asm` generate annotations in assembly files produced with the `-S` option as follows:

- `-fcode-asm` inserts code byte information in the assembly file
- `-fsource-asm` inserts high-level source code in the assembly file

In addition, the options `-fverbose-asm` and `-fnoverbose-asm` enable and disable, respectively, inserting comments containing compiler version and options used in the assembly file. The `-fverbose-asm` option is enabled by default when producing an assembly file with `-S`.

Compiler Output Options Summary

If no errors occur during processing, you can use the output files from a particular phase as input to a later compiler invocation. The executable file is produced when you do not specify any phase-limiting option. The filename of the first source or object file specified with an absent suffix, is the default for the executable object file from the linker.

The table below describes the options to control the output.

<table>
<thead>
<tr>
<th>Last Phase Completed</th>
<th>Option</th>
<th>Compiler Input</th>
<th>Compiler Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>preprocessing</td>
<td><code>-P</code>, <code>-E</code>, or <code>-EP</code></td>
<td>source files</td>
<td>preprocessed files, see <a href="#">Preprocessing</a></td>
</tr>
<tr>
<td>compile only</td>
<td><code>-c</code></td>
<td>source</td>
<td>Compile to object only (.o), do not link.</td>
</tr>
<tr>
<td>assembly only</td>
<td><code>-S</code></td>
<td>source</td>
<td>Compile to assembly file only (.s) and stop.</td>
</tr>
<tr>
<td>compilation, linking, or assembly</td>
<td><code>-o, name</code></td>
<td>source, assembly, or object files</td>
<td>Assigns a name of your choice to an output file</td>
</tr>
<tr>
<td>syntax checking</td>
<td><code>-y</code></td>
<td>source files</td>
<td>diagnostic list</td>
</tr>
</tbody>
</table>
Using the Assembler to Produce Object Code

By default the compiler generates an object file directly without going through the assembler. But if you want to link some specific input file to the Fortran project object file, you can use the -use_asm option to tell the compiler to use the Linux* Assembler for IA-32 systems or Itanium® Assembler for Itanium®-based systems.

```
prompt> ifc -use_asm file1.f
```

```
prompt> efc -use_asm file1.f
```

The above command generates an `file1.o` object file which you can link with the Fortran object file(s) of the whole project.

### Listing Options

The following options produce a source listing to the standard output, which by default is the screen.

- The `-list` option writes a listing of the source file to standard output (typically, your terminal screen), including any error or warning messages. The errors and warnings are also output to standard error, `stderr`.

- The `-list -showinclude` prints a source listing to `stdout` with contents of `include` files expanded.

### Linking

This topic describes the options that enable you to control and customize the linking with tools and libraries and define the output of the linking process. See the summary of linking options.

**Note**

These options are specified at compile time and have effect at the linking time.
Options to Link to Tools and Libraries

The following options enable you to link to various tools and libraries:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-Bdynamic</code></td>
<td>Used with <code>-lname</code> (see below), enables dynamic linking of libraries at run time. Compared to static linking, results in smaller executables.</td>
</tr>
<tr>
<td><code>-Bstatic</code></td>
<td>Enables linking a user's library statically.</td>
</tr>
<tr>
<td><code>-C90</code></td>
<td>Link with alternate I-O library for mixed output with the C language.</td>
</tr>
<tr>
<td><code>-i_dynamic</code></td>
<td>Enables to link the shared object versions of the Intel-provided libraries dynamically.</td>
</tr>
<tr>
<td><code>-lname</code></td>
<td>Link with a library indicated in name. For example, <code>-lm</code> indicates to link with the math library.</td>
</tr>
<tr>
<td><code>-Ldir</code></td>
<td>Instructs linker to search <code>dir</code> for libraries.</td>
</tr>
<tr>
<td><code>-posixlib</code></td>
<td>Enables or disable linking with POSIX* library.</td>
</tr>
<tr>
<td><code>-shared</code></td>
<td>Instructs the compiler to build the Dynamic Shared Object (DSO) instead of an executable.</td>
</tr>
<tr>
<td><code>-static</code></td>
<td>Enables to link shared libraries (.so) statically at compile time. Compared to dynamic linking, results in larger executables.</td>
</tr>
</tbody>
</table>

When `-static` is not used:

- `/lib/ld-linux.so.2` is linked dynamically
- `libm`, `libcxa`, and `libc` are linked dynamically
- all other libraries are linked statically

When `-static` is used:

- `/lib/ld-linux.so.2` is not linked
- all other libraries are linked statically

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-Vaxlib</code></td>
<td>Enable or disable linking with portability library.</td>
</tr>
</tbody>
</table>

Controlling Linking and its Output

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-Ldir</code></td>
<td>Instruct linker to search for <code>dir</code> libraries.</td>
</tr>
</tbody>
</table>
See Libraries for more information on using them.

### Suppressing Linking

Use the \(-c\) option to suppress linking. Entering the following command produces the object files `file.o` and `file2.o`, but does not link these files to produce an executable file.

**IA-32 compiler:**

```
prompt> ifc -c file.f file2.f
```

**Itanium® compiler:**

```
prompt> efc -c file.f file2.f
```

⚠️ **Note**

The preceding command does not link these files to produce an executable file.

### Debugging Options

This section describes the basic command line options that you can use as tools to debug your compilation and to display and check compilation errors. The options in this section enable you to:

- support for symbolic debugging
- compile only designated lines and debug statements
- check the source files for syntax errors before creating output file

### Support for Symbolic Debugging

Use the \(-g\) option to direct the compiler to generate code to support symbolic debugging. For example:

**IA-32 applications:** `prompt> ifc -g prog1.f`

**Itanium®-based applications:** `prompt> efc -g prog1.f`

The compiler lets you generate code to support symbolic debugging while the \(-O1\), or \(-O2\) optimization options are specified on the command line along with \(-g\).

If you specify the \(-O1\), or \(-O2\) options with the \(-g\) option, you can receive these results:

- some of the debugging information returned may be inaccurate as a side-effect of
optimization.

- for IA-32 applications, `-O1`, or `-O2` options disable the `-fp` option. See `-fp Option` and Debugging.

### Debugging and Assembling

The compiler does not support the generation of debugging information in assembly files. If you specify the `-g` option with `-S`, the assembly listing file is generated without debugging information, but if you further produce an object file, it will contain debugging information. If you link the object file and then use the GDB debugger on it, you will get full symbolic representation.

### Compiling Source Lines with Debugging Statements, `-DD`

This option is useful for the inclusion or exclusion of debugging lines. Use the `-DD` option to compile source lines containing user debugging statements.

#### The `-DD` Option

Debugging statements included in a Fortran program source are indicated by the letter D in column 1. The `-DD` option instructs the compiler to treat a D in column 1 of Fortran source as a space character. The rest of that line is then parsed as a normal Fortran statement.

For example, to compile any debugging statements in program `prog1.f`, enter the following command:

```bash
prompt> ifc -DD prog1.f
```

The above command causes the debugging statement

```fortran
D PRINT *, "I= ", I
```

embedded in the `prog1.f` to execute and print lines designated for debugging.

By default, the compiler takes no action on these statements. In the following example, if `-DD` is not specified (default), the D line is ignored:

```fortran
  do 10 i = 1, n
    a(i) = b(i)
  D    write (*,*) a(i)
  10 continue
```

But when `-DD` is specified, the compiler sees a `write` statement as if the code is:
The `-DX` and `-DY` Options

Two additional distinctions to compile source lines containing user debugging statements are also available with these variations of the `-DD` option:

- `-DX` compiles debug statements indicated by an `X` or an `x` in column 1; if this option is not set these lines are treated as comments.
- `-DY` compiles debug statements indicated by an `Y` or an `y` in column 1; if this option is not set these lines are treated as comments.

Parsing for Syntax Only

Use the `-y` or `-syntax` option to stop processing source files after they have been parsed for Fortran language errors. This option gives you a way to check quickly whether sources are syntactically and semantically correct. The compiler creates no output file. In the following example, the compiler checks a file named `prog1.f`. Any diagnostics appear on the standard error output and in a listing, if you have requested one.

**IA-32 applications:** `prompt>ifc -y prog1.f`

**Itanium®-based applications:** `prompt>efc -y prog1.f`

Debugging and Optimizations

It is best to make your optimization and/or debugging choices explicit:

- If you need to debug your program excluding any optimization effect, use the `-O0` option, which turns off all the optimizations.
- If you need to debug while still use optimizations, you can specify the `-O1` or `-O2` options on the command line along with `-g`.

If you do not make your optimization choice explicit when `-g` is specified, the `-g` option implicitly disables optimization (as if `-O0` were specified).

**-fp Option and Debugging (IA-32 only)**
The \texttt{-fp} option disables use of the \texttt{ebp} register in optimizations, and can result in slightly less efficient code. With this option, the compiler generates code for IA-32-targeted compilations without turning off optimization, so that a debugger can still produce a stack backtrace.

If you specify the \texttt{-O1} or \texttt{-O2} options, the \texttt{-fp} option is disabled. If you specify the \texttt{-O0} option, \texttt{-fp} is enabled. Remember that the \texttt{-fp} option affects IA-32 applications only.

\section*{Summary}

Refer to the table below for the summary of the effects of using the \texttt{-g} option with the optimization options.

<table>
<thead>
<tr>
<th>These options</th>
<th>Imply these results</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{-g}</td>
<td>debugging information produced, \texttt{-O0} enabled, \texttt{-fp} enabled for IA-32-targeted compilations.</td>
</tr>
<tr>
<td>\texttt{-g \ -O1}</td>
<td>debugging information produced, \texttt{-O1} optimizations enabled, \texttt{-fp} disabled for IA-32-targeted compilations</td>
</tr>
<tr>
<td>\texttt{-g \ -O2}</td>
<td>debugging information produced, \texttt{-O2} optimizations enabled, \texttt{-fp} disabled for IA-32-targeted compilations</td>
</tr>
<tr>
<td>\texttt{-g \ -O3 \ -fp}</td>
<td>debugging information produced, \texttt{-O3} optimizations enabled, \texttt{-fp} enabled for IA-32-targeted compilations.</td>
</tr>
<tr>
<td>\texttt{-g \ -ip}</td>
<td>limited debugging information produced, \texttt{-ip} option enabled.</td>
</tr>
</tbody>
</table>
Fortran Language Options

The Intel® Fortran Compiler implements Fortran language-specific options, which enable you to set or specify:

- set data types and sizes
- define source program characteristics
- set arguments and variables
- allocate common blocks

For the size or number of Fortran entities the Intel® Fortran Compiler can process, see Maximum Size and Number table.

Setting Integer and Floating-point Data Types

See the summary of these options.

Integer Data

The \(-i2\), \(-i4\), and \(-i8\) options specify that all quantities of INTEGER type and unspecified KIND occupy two, four or eight bytes, respectively. All quantities of LOGICAL type and unspecified KIND also occupy two, four or eight bytes, respectively.

All logical constants and all small integer constants occupy two, four or eight bytes, respectively.

The default is four bytes, \(-i4\).

Floating-point Data

The \(-r{4|8|16}\) option defines the KIND for real variables in 4, 8, and 16 bytes. The default is \(-r4\).

The \(-r8\), \(-autodouble\), and \(-r16\) options specify floating-point data.

The \(-r8\) option directs the compiler to treat all variables, constants, functions and intrinsics as DOUBLE PRECISION, and all complex quantities as DOUBLE COMPLEX. The \(-autodouble\) option has the same effect as the \(-r8\) option.

The \(-r16\) option directs the compiler to treat all variables, constants, functions and
intrinsics as DOUBLE PRECISION, and all complex quantities as DOUBLE COMPLEX. This option changes the default size of real numbers to 16 bytes.

Source Program Features

The options that enable the compiler to process a source program in a beneficial way for or required by the application, can be divided in two groups described in the two sections below. See a summary of these options.

Program Structure and Format

DO loops

The -onetrip option directs the compiler to compile DO loops at least once. By default Fortran DO loops are not performed at all if the upper limit is smaller than the lower limit. The option -1 has the same effect. This supports old programs from the Fortran–66 standard, when all DO loops executed at least once.

Fixed Format Source

The -FI option specifies that all the source code is in fixed format; this is the default except for files ending with the extension .f, .for, .ftn.

-132 permits fixed form source lines to contain up to 132 characters. The -extend_source, option has the same effect as -132.

Free Format Source

-FR options Specifies that all the source code is in Fortran free format; this is the default for files ending with the suffix .f90.

Character Definitions

The -pad_source option enforces the acknowledgment of blanks at the end of a line.

The -us option appends an underscore to external subroutine names. -nus disables appending an underscore to an external subroutine name.

The -nus[file] option directs to not append an underscore to subroutine names listed in file. Useful when linking with C routines.

The -nbs option directs the compiler to treat backslash (\) as a normal graphic character, not an escape character. This may be necessary when transferring programs from non-UNIX* environments, for example from VAX* VMS*. See Escape Characters.

Compatibility with Platforms and Compilers
This group discusses options that enable compatibility with other compilers.

**Cross-platform**

The `-ansi_alias[-]` enables (default) or disables assumption of the program’s ANSI conformance. Provides cross-platform compatibility. This option is used to make assumptions about out-of-bound array references and pointer references. For gcc compatibility, the `-ansi_alias` option is accepted. The option is ON by default.

The option directs the compiler to assume the following:

- Arrays are not accessed out of arrays’ bounds.
- Pointers are not cast to non-pointer types and vice-versa.
- References to objects of two different scalar types cannot alias. For example, an object of type `integer` cannot alias with an object of type `real` or an object of type `real` cannot alias with an object of type `double precision`.

If your program satisfies the above conditions, setting the `-ansi_alias` option will help the compiler better optimize the program. However, if your program may not satisfy one of the above conditions, the option must be disabled, as it can lead the compiler to generate incorrect code.

**DEC* VMS**

The `-dps,` option enables (default) or disables DEC* parameter statement recognition. Basically, the `-dps` option determines how the compiler treats the alternate syntax for `PARAMETER` statements, which is:

```
PARAMETER par1=exp1 [, par2=exp2] ...
```

This form does not have parentheses around the assignment of the constant to the parameter name. With this form, the type of the parameter is determined by the type of the expression being assigned to it and not by any implicit typing.

By default, the compiler allows the alternate syntax for `PARAMETER` statements, `-dps`. To disable this form, specify `-nodps`.

The `-vms` option enables support for extensions to Fortran that were introduced by Digital* VMS Fortran compilers. The extensions are as follows:

- The compiler permits shortened, apostrophe-separated syntax for parameters in I/O statements. For example, a statement of the form: `WRITE (4 ' 7) FOO` is permitted and is equivalent to `WRITE (UNIT=4, REC= 7) FOO`.
- The compiler assumes that the value specified for `RECL` in an `OPEN` statement is
given in words rather than bytes. This option also implies `-dps`, even though `-dps` is on by default.

**C Language**

The `-lowercase` maps external routine names and symbol names (linker) to lowercase alphabetic characters. This option is useful when mixing Fortran with C programs.

The `-uppercase` maps external names to uppercase alphabetic characters.

⚠️ **Note**

Do not use the `-uppercase` option in combination with `-Vaxlib` or `-posixlib`.

**Escape Characters**

For compatibility with C usage, the backslash (\) is normally used in Intel® Fortran Compiler as an escape character. It denotes that the following character in the string has a significance which is not normally associated with the character. The effect is to ignore the backslash character, and either substitute an alternative value for the following character or to interpret the character as a quoted value.

The escape characters recognized, and their effects, are described in the table below. Thus, `'ISN\'T'` is a valid string. The backslash (\) is not counted in the length of the string.

**Escape Characters and Their Effect**

<table>
<thead>
<tr>
<th>Escape Character</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>\n</td>
<td>new line</td>
</tr>
<tr>
<td>\t</td>
<td>horizontal tab</td>
</tr>
<tr>
<td>\v</td>
<td>vertical tab</td>
</tr>
<tr>
<td>\b</td>
<td>backspace</td>
</tr>
<tr>
<td>\f</td>
<td>form feed</td>
</tr>
<tr>
<td>\0</td>
<td>null</td>
</tr>
<tr>
<td>'</td>
<td>apostrophe (does not terminate a string)</td>
</tr>
<tr>
<td>&quot;</td>
<td>double quote (does not terminate a string)</td>
</tr>
</tbody>
</table>
| \\\n| (a single backslash)
| \x               | \(x, where \(x\) is any other character \) |

**Line Terminators**
This information is useful for recent Linux* users after working with Windows*. The line terminators are different between Linux and Windows. On Windows, line terminators are \r\n while on Linux they are just \n. Typically, a file transfer program will take care of this issue for you if you transfer the file in text mode. If the file is transferred in binary mode (but the file is really text file), the problem will not be resolved by FTP.

## Setting Arguments and Variables

These options can be divided into two major groups discussed below. See a summary of [these options](#).

### Automatic Allocation of Variables to Stacks

- **-auto**

  This option makes all local variables AUTOMATIC. Causes all variables to be allocated on the stack, rather than in local static storage. Variables defined in a procedure are otherwise allocated to the stack only if they appear in an AUTOMATIC statement, or if the procedure is recursive and the variables do not have the SAVE or ALLOCATABLE attributes. The option does not affect variables that appear in an EQUIVALENCE or SAVE statement, or those that are in COMMON. May provide a performance gain for your program, but if your program depends on variables having the same value as the last time the routine was invoked, your program may not function properly.

- **-auto_scalar**

  This option causes scalar variables of rank 0, except for variables of the COMPLEX or CHARACTER types, to be allocated on the stack, rather than in local static storage. Does not affect variables that appear in an EQUIVALENCE or SAVE statement, or those that are in COMMON. -auto_scalar may provide a performance gain for your program, but if your program depends on variables having the same value as the last time the routine was invoked, your program may not function properly. Variables that need to retain their values across subroutine calls should appear in a SAVE statement. This option is similar to -auto, which causes all local variables to be allocated on the stack. The difference is that -auto_scalar allocates only variables of rank 0 on the stack.

  -auto_scalar enables the compiler to make better choices about which variables should be kept in registers during program execution. This option is on by default.

- **-save and -zero**

  Forces the allocation of variables, except local variables within a recursive routine, in static storage. If a routine is invoked more than once, this option forces the local variables to retain their values from the last invocation terminated. This may cause a performance degradation and may change the output of your program for floating-point values as it forces operations to be carried out in memory rather than in registers which in turn causes

The -zero option presets uninitialized variables to zero. It is most commonly used in conjunction with -save.

**Alignment, Aliases, Implicit None**

**Alignment**

The -align option is a front-end option that changes alignment of variables in a COMMON block.

Example:

```fortran
COMMON /BLOCK1/CH,DOUB,CH1,INT
INTEGER INT
CHARACTER(LEN=1) CH,CH1
DOUBLE PRECISION DOUB
END
```

The -align option enables padding inserted to assure alignment of DOUB and INT on natural alignment boundaries. The -noalign option disables padding.

**Aliases**

The -common_args option assumes that the "by-reference" subprogram arguments may have aliases of one another.

**Implicit None**

The -u and -implicitnone options set IMPLICIT NONE as the default.

**Preventing CRAY* Pointer Aliasing**

Option -safe_cray_ptr specifies that the CRAY* pointers do not alias with other variables. The default is OFF.

Consider the following example.

```fortran
pointer (pb, b)
pb = getstorage()
do i = 1, n
  b(i) = a(i) + 1
```
When -safe_cray_ptr is not specified (default), the compiler assumes that b and a are aliased. To prevent such an assumption, specify this option, and the compiler will treat b(i) and a(i) as independent of each other.

However, if the variables are intended to be aliased with CRAY pointers, using the -safe_cray_ptr option produces incorrect result. For the code example below, -safe_cray_ptr should not be used.

```fortran
pb = loc(a(2))
do i=1, n
  b(i) = a(i) +1
endo
```

### Allocating Common Blocks

The following two options are used for the common blocks:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Qdyncom&quot;blk1,blk2 ...&quot;</td>
<td>Dynamically allocates COMMON blocks at runtime. See section Dynamic Common Option that follows.</td>
</tr>
<tr>
<td>-Qloccom&quot;blk1,blk2, ...&quot;</td>
<td>Enables local allocation of given COMMON blocks at run time. See Allocating Memory to Dynamic COMMON Blocks.</td>
</tr>
</tbody>
</table>

### Dynamic Common Option

The -Qdyncom option dynamically allocates COMMON blocks at runtime. This option on the compiler command line designates a COMMON block to be dynamic, and the space for its data is allocated at runtime, rather than compile time. On entry to each routine containing a declaration of the dynamic COMMON block, a check is made of whether space for the COMMON block has been allocated. If the dynamic COMMON block is not yet allocated, space is allocated at the check time.

The following example of a command-line specifies the dynamic common option with the names of the COMMON blocks to be allocated dynamically at runtime:

**IA-32 applications:**

`prompt>ifc -Qdyncom"BLK1,BLK2,BLK3" test.f`

**Itanium®-based applications:**

`prompt>efc -Qdyncom"BLK1,BLK2,BLK3" test.f`
where BLK1, BLK2, and BLK3 are the names of the COMMON blocks to be made dynamic.

Allocating Memory to Dynamic Common Blocks

The runtime library routine, \texttt{f90\_dyncom}, performs memory allocation. The compiler calls this routine at the beginning of each routine in a program that contains a dynamic COMMON block. In turn, this library routine calls \_FTN \_ALLOC () to allocate memory. By default, the compiler passes the size in bytes of the COMMON block as declared in each routine to \texttt{f90\_dyncom}, and then on to \_FTN\_ALLOC (). If you use the nonstandard extension having the COMMON block of the same name declared with different sizes in different routines, you may get a runtime error depending upon the order in which the routines containing the COMMON block declarations are invoked.

The runtime library contains a default version of \_FTN\_ALLOC (), which simply allocates the requested number of bytes and returns.

Why Use a Dynamic Common

One of the primary reasons for using dynamic COMMON is to enable you to control the COMMON block allocation by supplying your own allocation routine. To use your own allocation routine, you should link it ahead of the runtime library routine. This routine must be written in the C language to generate the correct routine name.

The routine prototype is as follows:

\begin{verbatim}
void _FTN_ALLOC(void **mem, int *size, char *name);
\end{verbatim}

where

<table>
<thead>
<tr>
<th>mem</th>
<th>is the location of the base pointer of the COMMON block which must be set by the routine to point to the block memory allocated.</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>is the integer number of bytes of memory that the compiler has determined are necessary to allocate for the COMMON block as it was declared in the program. You can ignore this value and use whatever value is necessary for your purpose.</td>
</tr>
</tbody>
</table>

\begin{footnotesize}
\begin{itemize}
\item Note
\end{itemize}
\end{footnotesize}

You must return the size in bytes of the space you allocate. The library routine that calls \_FTN \_ALLOC () ensures that all other occurrences of this common block fit in the space you allocated. Return the size in bytes of the space you allocate by modifying the size parameter.
Rules of Using Dynamic Common Option

The following are some limitations that you should be aware of when using the dynamic common option:

- If you use the technique of implementing your own allocation routine, then you should specify only one dynamic COMMON block on the command line. Otherwise, you may not know the name of the COMMON block for which you are allocating storage.

- An entity in a dynamic COMMON may not be initialized in a DATA statement.

- Only named COMMON blocks may be designated as dynamic COMMON.

- An entity in a dynamic COMMON must not be used in an EQUIVALENCE expression with an entity in a static COMMON or a DATA-initialized variable.
Compiler Optimizations

The variety of optimizations used by the Intel® Fortran Compiler enable you to enhance the performance of your application. Each optimization is performed by a set of options, see Compiler Options by Functional Groups Overview and Application Performance Optimizations Options section.

In addition to optimizations invoked by the compiler command line options, the compiler includes features which enhance your application performance such as directives, intrinsics, runtime library routines and various utilities. These features are discussed in the Optimization Support Features section.

Optimizing Different Application Types

Each of the command-line options: -O, -O1, -O2 and -O3 turn on several compiler capabilities. See the summary of these options.

The following table provides a summary of the optimizations that the compiler applies when you invoke -O, -O1 and/or -O2, or -O3 optimizations.

<table>
<thead>
<tr>
<th>Option</th>
<th>Optimization</th>
<th>Affected Aspect of Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>-O1, -O2</td>
<td>global register allocation</td>
<td>register use</td>
</tr>
<tr>
<td>-O1, -O2</td>
<td>instruction scheduling</td>
<td>instruction reordering</td>
</tr>
<tr>
<td>-O1, -O2</td>
<td>register variable detection</td>
<td>register use</td>
</tr>
<tr>
<td>-O1, -O2</td>
<td>common subexpression elimination</td>
<td>constants and expression evaluation</td>
</tr>
<tr>
<td>-O1, -O2</td>
<td>dead-code elimination</td>
<td>instruction sequencing</td>
</tr>
<tr>
<td>-O1, -O2</td>
<td>variable renaming</td>
<td>register use</td>
</tr>
<tr>
<td>-O1, -O2</td>
<td>copy propagation</td>
<td>register use</td>
</tr>
<tr>
<td>-O1, -O2</td>
<td>constant propagation</td>
<td>constants and expression evaluation</td>
</tr>
<tr>
<td>-O1, -O2</td>
<td>strength reduction-induction variable</td>
<td>simplification instruction, selection-sequencing</td>
</tr>
<tr>
<td>-O1, -O2</td>
<td>tail recursion elimination</td>
<td>calls, further optimization</td>
</tr>
<tr>
<td>-O2</td>
<td>software pipelining for Itanium-based application</td>
<td>calls, further optimization</td>
</tr>
<tr>
<td>-O2</td>
<td>loop unrolling; inlining of intrinsics</td>
<td>calls, further optimization</td>
</tr>
</tbody>
</table>
Setting Optimizations with −O Options

For IA-32 and Itanium® architectures, these options behave in a different way. To specify the optimizations for your program, use options depending on the target architecture as explained in the tables that follow.

Itanium® Compiler

<table>
<thead>
<tr>
<th>Option</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>−O1</td>
<td>Optimizes to favor code size. Enables the same optimizations as −O except for loop unrolling and software pipelining. At −O1 the global code scheduler is tuned to favor code size.</td>
</tr>
<tr>
<td>−O, −O2</td>
<td>Turn the software pipelining ON. Generally, −O or −O2 are recommended over −O1.</td>
</tr>
</tbody>
</table>

IA-32 Compiler

<table>
<thead>
<tr>
<th>Option</th>
<th>Effect</th>
</tr>
</thead>
</table>
| −O,−O1,−O2 | Optimize to favor code speed. Disable option −fp. The −O2 option is ON by default. Inlines intrinsics.  
Example: large database applications, code with many branches and not dominated by loops |
| −O3     | Enables −O2 option with more aggressive optimization. Optimizes for maximum speed, but does not guarantee higher performance unless loop and memory access transformation take place. In conjunction with −a×K and −xK options, this option causes the compiler to perform more aggressive data dependency analysis than for −O2. This may result in longer compilation times. |

IA-32 and Itanium Compilers

For IA-32 and Itanium architectures, the options can behave in a different way. To specify the optimizations for your program, use options depending on the target architecture as follows.
### Restricting Optimizations

The following options restrict or preclude the compiler’s ability to optimize your program:

<table>
<thead>
<tr>
<th>Option</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>-O2</td>
<td>ON by default. -O2 turns ON intrinsics inlining. Used for best overall performance on typical integer applications that do not make heavy use of floating point math. Enables the following capabilities for performance gain:</td>
</tr>
<tr>
<td></td>
<td>• constant propagation</td>
</tr>
<tr>
<td></td>
<td>• copy propagation</td>
</tr>
<tr>
<td></td>
<td>• dead-code elimination</td>
</tr>
<tr>
<td></td>
<td>• global register allocation</td>
</tr>
<tr>
<td></td>
<td>• global instruction scheduling and control speculation</td>
</tr>
<tr>
<td></td>
<td>• loop unrolling</td>
</tr>
<tr>
<td></td>
<td>• optimized code selection</td>
</tr>
<tr>
<td></td>
<td>• partial redundancy elimination</td>
</tr>
<tr>
<td></td>
<td>• strength reduction/induction variable simplification</td>
</tr>
<tr>
<td></td>
<td>• variable renaming</td>
</tr>
<tr>
<td></td>
<td>• predication</td>
</tr>
<tr>
<td></td>
<td>• software pipelining</td>
</tr>
<tr>
<td>-O3</td>
<td>Enables -O2 option with more aggressive optimization. Optimizes for maximum speed, but may not improve performance for some programs. Used mostly for applications that make heavy use of floating-point calculations on large data sets.</td>
</tr>
</tbody>
</table>
Floating-point Arithmetic Precision

The options described in this section all provide optimizations with varying degrees of precision in floating-point (FP) arithmetic for IA-32 and Itanium® compiler. See the FP arithmetic precision options [summary](#).

The `-mp` and `-mp1` options are used by both architectures. These options improve floating-point precision, but also affect the application performance. See more details about these options in [Improving/Restricting FP Arithmetic Precision](#).

The FP options provide optimizations with varying degrees of precision in floating-point arithmetic. The option that disables these optimizations is `-O0`.

### `-mp` Option

Use `-mp` to limit floating-point optimizations and maintain declared precision. For example, the Intel® Fortran Compiler can change floating-point division computations into multiplication by the reciprocal of the denominator. This change can alter the results of floating point division computations slightly. The `-mp` switch may slightly reduce execution speed. See [Improving/Restricting FP Arithmetic Precision](#) for more detail.

### `-mp1` Option

Use the `-mp1` option to restrict floating-point precision to be closer to declared precision with less impact to performance than with the `-mp` option. The option will ensure the out-of-range check of operands of transcendental functions and improve accuracy of floating-point compares.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-O0</code></td>
<td>Disables optimizations <code>-O1</code>, <code>-O2</code>, and-or <code>-O3</code>. Enables <code>-fp</code> option.</td>
</tr>
<tr>
<td><code>-mp</code></td>
<td>Restricts optimizations that cause some minor loss or gain of precision in floating-point arithmetic to maintain a declared level of precision and to ensure that floating-point arithmetic more nearly conforms to the ANSI and IEEE* standards. See <code>-mp</code> option for more details.</td>
</tr>
<tr>
<td><code>-nolib_inline</code></td>
<td>Disables inline expansion of intrinsic functions.</td>
</tr>
</tbody>
</table>
Floating-point Arithmetic Precision for IA-32 Systems

-prec_div Option

The Intel® Fortran Compiler can change floating-point division computations into multiplication by the reciprocal of the denominator. Use -prec_div to disable floating point division-to-multiplication optimization resulting in more accurate division results. May have speed impact.

-pc{32|64|80} Option

Use the -pc{32|64|80} option to enable floating-point significand precision control. Some floating-point algorithms, created for specific 32- and Itanium®-based systems, are sensitive to the accuracy of the significand or fractional part of the floating-point value. Use appropriate version of the option to round the significand to the number of bits as follows:

- pc32: 24 bits (single precision)
- pc64: 53 bits (double precision)
- pc80: 64 bits (extended precision)

The default version is -pc80 for full floating-point precision.

This option enables full optimization. Using this option does not have the negative performance impact of using the -mp option because only the fractional part of the floating-point value is affected. The range of the exponent is not affected.

⚠️ Note

This option only has effect when the module being compiled contains the main program.

⚠️ Caution

A change of the default precision control or rounding mode (for example, by using the -pc32 option or by user intervention) may affect the results returned by some of the mathematical functions.

Rounding Control, -rcd, -fp_port
The Intel Fortran Compiler uses the `-rcd` option to disable changing of rounding mode for floating-point-to-integer conversions.

The system default floating-point rounding mode is round-to-nearest. This means that values are rounded during floating-point calculations. However, the Fortran language requires floating-point values to be truncated when a conversion to an integer is involved. To do this, the compiler must change the rounding mode to truncation before each floating-point conversion and change it back afterwards.

The `-rcd` option disables the change to truncation of the rounding mode for all floating-point calculations, including floating-point-to-integer conversions. Turning on this option can improve performance, but floating-point conversions to integer will not conform to Fortran semantics.

You can also use the `-fp_port` option to round floating-point results at assignments and casts. This option has some speed impact.

**Floating-point Arithmetic Precision for Itanium®-based Systems**

The following Intel® Fortran Compiler options enable you to control the compiler optimizations for floating-point computations on Itanium®-based systems.

**Contraction of FP Multiply and Add/Subtract Operations**

`-IPF_fma[-]` enables or disables the contraction of floating-point multiply and add/subtract operations into a single operations. Unless `-mp` is specified, the compiler tries to contract these operations whenever possible. The `-mp` option disables the contractions.

`-IPF_fma` and `-IPF_fma-` can be used to override the default compiler behavior. For example, a combination of `-mp` and `-IPF_fma` enables the compiler to contract operations:

```
prompt>efc -mp -IPF_fma myprog.f
```

**FP Speculation**

`-IPF_fp_speculationmode` sets the compiler to speculate on floating-point operations in one of the following *modes*:

`fast`: sets the compiler to speculate on floating-point operations; this is the default.

`safe`: enables the compiler to speculate on floating-point operations only when it is safe;

`strict`: enables the compiler's speculation on floating-point operations preserving
floating-point status in all situations. In the current version, this mode disables the speculation of floating-point operations (same as off).

*off*: disables the speculation on floating-point operations.

**FP Operations Evaluation**

\texttt{-IPF\_flt\_eval\_method\{0|2\}} option directs the compiler to evaluate the expressions involving floating-point operands in the following way:

\texttt{-IPF\_flt\_eval\_method0} directs the compiler to evaluate the expressions involving floating-point operands in the precision indicated by the variable types declared in the program.

\texttt{-IPF\_flt\_eval\_method2} is not supported in the current version.

**Controlling Accuracy of the FP Results**

\texttt{-IPF\_fltacc} disables the optimizations that affect floating-point accuracy. The default is \texttt{-IPF\_fltacc} to enable such optimizations.

The Itanium® compiler may reassociate floating-point expressions to improve application performance. Use \texttt{-IPF\_fltacc} or \texttt{-mp} to disable or restrict these floating-point optimizations.

**Flushing to Zero Denormal Values, \texttt{-ftz [-]}**

Option \texttt{-ftz [-]} flushes denormal results to zero when the application is in the gradual underflow mode. Flushing the denormal values to zero with \texttt{-ftz} may improve performance of your application.

\begin{quote}
\textbf{Note}

Use this option if the denormal values are not critical to application behavior.
\end{quote}

The default status of \texttt{-ftz [-]} is OFF. By default, the compiler lets results gradually underflow.

**Pro's and Con's**

With the default \texttt{-O2} option, \texttt{-ftz [-]} is OFF. The \texttt{-O3} option turns \texttt{-ftz [-]} on. **Note** that \texttt{-ftz [-]} only needs to be used on the source that contains function \texttt{main()} to turn the FTZ mode on. The initial thread, and any threads subsequently created by that process, will operate in FTZ mode.

If the \texttt{-ftz} option produces undesirable results of the numerical behavior of your program, you can turn the FTZ mode off by using \texttt{-ftz-} in the command line while still benefiting from the \texttt{-O3} optimizations:
prompt>`efe -O3 -ftz- myprog.f`

## Improving/Restricting FP Arithmetic Precision

The `-mp` and `-mp1` options maintain and restrict, respectively, floating-point precision, but also affect the application performance. The `-mp1` option causes less impact on performance than the `-mp` option. `-mp1` ensures the out-of-range check of operands of transcendental functions and improve accuracy of floating-point compares.

The `-mp` option restricts some optimizations to maintain declared precision and to ensure that floating-point arithmetic conforms more closely to the ANSI and IEEE* standards. This option causes more frequent stores to memory, or disallow some data from being register candidates altogether. The Intel architecture normally maintains floating point results in registers. These registers are 80 bits long, and maintain greater precision than a double-precision number. When the results have to be stored to memory, rounding occurs. This can affect accuracy toward getting more of the "expected" result, but at a cost in speed.

The `-pc{32|64|80}` option (IA-32 only) can be used to control floating point accuracy and rounding, along with setting various processor IEEE flags.

For most programs, specifying this option adversely affects performance. If you are not sure whether your application needs this option, try compiling and running your program both with and without it to evaluate the effects on performance versus precision.

Specifying this option has the following effects on program compilation:

- **On IA-32 systems**, floating-point user variables declared as floating-point types are not assigned to registers.

- **On Itanium®-based systems**, floating-point user variables may be assigned to registers. The expressions are evaluated using precision of source operands. The compiler will not use Floating-point Multiply and Add (FMA) function to contract multiply and add/subtract operations in a single operation. The contractions can be enabled by using `-IPF_fma` option. The compiler will not speculate on floating-point operations that may affect the floating-point state of the machine. See [Floating-point Arithmetic Precision for Itanium-based Systems](#).

- Floating-point arithmetic comparisons conform to IEEE 754.

- The exact operations specified in the code are performed. For example, division is never changed to multiplication by the reciprocal.

- The compiler performs floating-point operations in the order specified without reassociation.

- The compiler does not perform the constant folding on floating-point values. Constant
folding also eliminates any multiplication by 1, division by 1, and addition or subtraction of 0. For example, code that adds 0.0 to a number is executed exactly as written. Compile-time floating-point arithmetic is not performed to ensure that floating-point exceptions are also maintained.

For IA-32 systems, whenever an expression is spilled, it is spilled as 80 bits (EXTENDED PRECISION), not 64 bits (DOUBLE PRECISION). Floating-point operations conform to IEEE 754. When assignments to type REAL and DOUBLE PRECISION are made, the precision is rounded from 80 bits (EXTENDED) down to 32 bits (REAL) or 64 bits (DOUBLE PRECISION). When you do not specify -O0, the extra bits of precision are not always rounded away before the variable is reused.

- Even if vectorization is enabled by the -xK option, the compiler does not vectorize reduction loops (loops computing the dot product) and loops with mixed precision types. Similarly, the compiler does not enable certain loop transformations. For example, the compiler does not transform reduction loops to perform partial summation or loop interchange.

Optimizing for Specific Processors

This section describes targeting a processor and processor dispatch and extensions support options. See the Optimizing for Specific Processors and Extensions summary.

The options -tpp{5|6|7} optimize for the IA-32 processors, and the options -tpp{1|2} optimize for the Itanium® processor family. The options -x{i|M|K|W} and -ax{i|M|K|W} generate code that is specific to processor-instruction extensions.

For example, on Pentium III processor, if you have mostly integer code and only a small portion of floating-point code, you may want to compile with -axM rather than -axK because MMX(TM) technology extensions perform the best with the integer data.

Note that these options are backward compatible with the extensions supported. On Intel® Pentium® 4, Intel® Xeon(TM) processors, and Intel® Pentium® M processor you can gear your code to any of the previous processors specified by K, M, or i.

Targeting a Processor, -tpp{ n }

The -tpp{ n } optimizes your application's performance for specific Intel processors.

Processors for IA-32 Systems

The -tpp5, -tpp6, and -tpp7 options optimize your application's performance for a specific Intel IA-32 processor. The resulting binary will also run on the processors listed in the table below.
Example

The invocations listed below each result in a compiled binary of the source program `prog.f` optimized for Pentium 4 and Intel Xeon processors by default. The same binary will also run on Pentium, Pentium Pro, Pentium II, and Pentium III processors.

```
prompt> ifc prog.f
```

```
prompt> ifc -tpp7 prog.f
```

However if you intend to target your application specifically to the Intel Pentium and Pentium with MMX technology processors, use the `-tpp5` option:

```
prompt> ifc -tpp5 prog.f
```

Processors for Itanium®-based Systems

The `-tpp1` and `-tpp2` options optimize your application's performance for a specific Intel Itanium® processor. The resulting binary will also run on the processors listed in the table below.

<table>
<thead>
<tr>
<th>Option</th>
<th>Optimizes your application for...</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-tpp1</code></td>
<td>Intel® Itanium® processor</td>
</tr>
<tr>
<td><code>-tpp2</code></td>
<td>Intel® Itanium® 2 processor</td>
</tr>
</tbody>
</table>

Example

The following invocation results in a compiled binary of the source program `prog.f` optimized for the Itanium 2 processor by default. The same binary will also run on Itanium processors.

```
prompt> efc prog.f
```

```
prompt> efc -tpp2 prog.f
```

However if you intend to target your application specifically to the Intel Itanium processor, use the `-tpp1` option:
Processor-Specific Exclusive Specialized Code (IA-32 only)

The \( -x\{M|i|K|W\} \) options target your program to run on a specific IA-32 processor by specifying the minimum set of processor instructions required for the processor that executes your program. The resulting code can contain unconditional use of the specified processor instructions.

<table>
<thead>
<tr>
<th>Option</th>
<th>Optimizes for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-xM)</td>
<td>Intel Pentium processors with MMX(TM) technology instructions.</td>
</tr>
<tr>
<td>(-xi)</td>
<td>Intel® Pentium® Pro and Pentium® II processors.</td>
</tr>
<tr>
<td>(-xK)</td>
<td>Intel Pentium III processors.</td>
</tr>
<tr>
<td>(-xW)</td>
<td>Intel Pentium 4 processors, Intel® Xeon(TM) processors, and Intel® Pentium® M processors.</td>
</tr>
</tbody>
</table>

To execute the program on x86 processors not provided by Intel Corporation, do not specify the \(-x\{M|i|K|W\}\) option.

Example

The invocation below compiles the program \( myprog.f \), using the \( K \) extension. The optimized binary will require Pentium III, Pentium 4, Intel Xeon processor, or Intel Pentium M processor to execute correctly. The resulting binary may not execute correctly on a Pentium, Pentium Pro, Pentium II, or Pentium with MMX technology processor, or on x86 processors not provided by Intel Corporation.

\[ prompt>ifc -xK myprog.f \]

⚠️ Caution

If a program compiled with \( -x\{M|i|K|W\} \) is executed on a processor that is not an Intel processor with the required extensions, it can fail with an illegal instruction exception, or it can display other unexpected behavior.

Processor Automatic Non-Exclusive Specialized Code (IA-32 only)

The \( -ax\{M|i|K|W\} \) options direct the compiler to find opportunities to generate
separate versions of functions that use instructions supported on specified Intel processors. If the compiler finds such an opportunity, it first checks whether generating a processor-specific version of a function results in a performance gain. If this is the case, the compiler generates both a processor-specific version of a function and a generic version of the function. The generic version will run on any IA-32 processor.

At run time, one of the two versions is chosen to execute, depending on the Intel processor in use. In this way, the program can benefit from performance gains on more advanced Intel processors, while still working properly on older IA-32 processors.

The disadvantages of using \(-ax\{M | i | K | W\}\) are:

- The size of the compiled binary increases because it contains both a processor-specific version and a generic version of the code.
- Performance is affected by the run-time checks to determine which code to use.

**Note**
Applications that you compile to optimize themselves for specific processors in this way will execute on any Intel IA-32 processor. Such compilations are, however, subject to any exclusive specialized code restrictions you impose during compilation with the \(-x\) option.

<table>
<thead>
<tr>
<th>Option</th>
<th>Optimizes for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-axM)</td>
<td>Intel Pentium processors with MMX(TM) technology instructions.</td>
</tr>
<tr>
<td>(-axi)</td>
<td>Intel® Pentium® Pro and Pentium® II processors.</td>
</tr>
<tr>
<td>(-axK)</td>
<td>Intel Pentium III processors. Implies M and i instructions.</td>
</tr>
<tr>
<td>(-axW)</td>
<td>Intel Pentium 4 processors, Intel® Xeon(TM) processors, and Intel® Pentium® M processors. Implies M, i, and K instructions.</td>
</tr>
</tbody>
</table>

**Example**

The compilation below will generate a single executable that includes:

- A generic version for use on any IA-32 processor
- A version optimized for Intel Pentium III processors, as long as there is a performance benefit.
- A version optimized for Intel Pentium 4 processors, Intel Xeon processors, and Intel Pentium M processors, as long as there is a performance benefit.

\textit{prompt}>ifc \ -axKW \ prog.f90

**Combining Processor Target and Dispatch**
## Options

The following table shows how to combine processor target and dispatch options to compile applications with different optimizations and exclusions.

<table>
<thead>
<tr>
<th>Optimize exclusively for...</th>
<th>...while optimizing without exclusion for...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentium® Processor</td>
<td>Pentium® Processor with MMX (TM) technology</td>
</tr>
<tr>
<td>Pentium Processor</td>
<td>-tpp5</td>
</tr>
<tr>
<td>Pentium Processor with MMX technology</td>
<td>N-A</td>
</tr>
<tr>
<td>Pentium Pro Processor</td>
<td>N-A</td>
</tr>
<tr>
<td>Pentium II Processor</td>
<td>N-A</td>
</tr>
<tr>
<td>Pentium III Processor</td>
<td>N-A</td>
</tr>
<tr>
<td>Pentium 4, Intel Xeon Processors</td>
<td>N-A</td>
</tr>
</tbody>
</table>

### Example of -x and -ax Combinations

If you wanted your application to

- always require the MMX technology extensions
- use Pentium Pro processor extensions when the processor it is run on offers it,
- and to not use them when it does not

you could generate such an application with the following command line:

```
prompt>ifc -xM -xi myprog.f
```

-xM above restricts the application to running on Pentium processors with MMX technology.
or later processors. If you wanted to enable the application to run on earlier generations of Intel® IA-32 processors as well, you would use the following command line:

```
prompt> ifc -axM myprog.f
```

This compilation generates optimized code for processors that support both the \( i \) and \( M \) extensions, but the compiled program will run on any IA-32 processor.

**Interprocedural Optimizations**

Use `–ip` and `–ipo` to enable interprocedural optimizations (IPO), which enable the compiler to analyze your code to determine where you can benefit from the optimizations listed in tables that follow. See [IPO options summary](#).

**IA-32 and Itanium®-based applications**

<table>
<thead>
<tr>
<th>Optimization</th>
<th>Affected Aspect of Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>inline function expansion</td>
<td>calls, jumps, branches, and loops</td>
</tr>
<tr>
<td>interprocedural constant propagation</td>
<td>arguments, global variables, and return values</td>
</tr>
<tr>
<td>monitoring module-level static variables</td>
<td>further optimizations, loop invariant code</td>
</tr>
<tr>
<td>dead code elimination</td>
<td>code size</td>
</tr>
<tr>
<td>propagation of function characteristics</td>
<td>call deletion and call movement</td>
</tr>
<tr>
<td>multifile optimization</td>
<td>affects the same aspects as <code>–ip</code>, but across multiple files</td>
</tr>
</tbody>
</table>

**IA-32 applications only**

<table>
<thead>
<tr>
<th>Optimization</th>
<th>Affected Aspect of Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>passing arguments in registers</td>
<td>calls, register usage</td>
</tr>
<tr>
<td>loop-invariant code motion</td>
<td>further optimizations, loop invariant code</td>
</tr>
</tbody>
</table>

Inline function expansion is one of the main optimizations performed by the interprocedural optimizer. For function calls that the compiler believes are frequently executed, the compiler might decide to replace the instructions of the call with code for the function itself.

With `–ip`, the compiler performs inline function expansion for calls to procedures defined within the current source file. However, when you use `–ipo` to specify multifile IPO, the compiler performs inline function expansion for calls to procedures defined in separate files.

To disable the IPO optimizations, use the `–O0` option.
Multifile IPO Overview

Multifile IPO obtains potential optimization information from individual program modules of a multifile program. Using the information, the compiler performs optimizations across modules.

Building a program is divided into two phases: compilation and linkage. Multifile IPO performs different work depending on whether the compilation, linkage or both are performed.

Compilation Phase

As each source file is compiled, multifile IPO stores an intermediate representation (IR) of the source code in the object file, which includes summary information used for optimization.

By default, the compiler produces "mock" object files during the compilation phase of multifile IPO. Generating mock files instead of real object files reduces the time spent in the multifile IPO compilation phase. Each mock object file contains the IR for its corresponding source file, but no real code or data. These mock objects must be linked using the -ipo option in ifc/efc or using the xild tool. (See Creating a Multifile IPO Executable with xild.)

Note
Failure to link "mock" objects with ifc/efc and -ipo or xild will result in linkage errors. There are situations where mock object files cannot be used. See Compilation with Real Object Files for more information.

Linkage Phase

When you specify -ipo, the compiler is invoked a final time before the linker. The compiler performs multifile IPO across all object files that have an IR.

Note
The compiler does not support multifile IPO for static libraries (.a files). See Compilation with Real Object Files for more information.

-ipo enables the driver and compiler to attempt detecting a whole program automatically. If a whole program is detected, the interprocedural constant propagation, stack frame alignment, data layout and padding of common blocks perform more efficiently, while more dead functions get deleted. This option is safe.

Creating a Multifile IPO Executable with
Command Line

Enable multifile IPO for compilations targeted for IA-32 architecture and for compilations targeted for Itanium® architecture as follows in the example below.

Compile your source files with -ipo as follows:

Compile source files to produce object files:

```
prompt> ifc -ipo -c a.f b.f c.f
```

Produces a.o, b.o, and c.o object files containing Intel compiler intermediate representation (IR) corresponding to the compiled source files a.f, b.f, and c.f. Using -c to stop compilation after generating .o files is required. You can now optimize interprocedurally.

Link object files to produce application executable:

```
prompt> ifc -o ipo_file -ipo a.o b.o c.o
```

The ifc command performs IPO for objects containing IR and creates a new list of object (s) to be linked. The ifc command calls GCC ld to link the specified object files and produce ipo_file.exe specified by the -o option. Multifile IPO is applied only to the source files that have an IR, otherwise the object file passes to link stage.

The -oname option stores the executable in ipo_file. Multifile IPO is applied only to the source files that have an IR, otherwise the object file passes to link stage.

For efficiency, combine steps 1 and 2:

```
prompt> ifc -ipo -o ipo_file a.f b.f c.f
```

For Itanium®-based applications, use the same steps with the efc command.

Instead of ifc or efc, you can use the xild tool.

For a description of how to use multifile IPO with profile information for further optimization, see Example of Profile-Guided Optimization.

Creating a Multifile IPO Executable Using xild

Use the Intel® linker, xild, instead of step 2 in Creating a Multifile IPO Executable with Command Line. The Intel linker xild performs the following steps:

1. Invokes the Intel compiler to perform multifile IPO if objects containing IR are found.
2. Invokes GCC ld to link the application.

The command-line syntax for xild is the same as that of the GCC linker:

```
prompt>xild [<options>] <LINK_commandline>
```

where:

- `[<options>]` (optional) may include any GCC linker options or options supported only by xild.
- `<LINK_commandline>` is your linker command line containing a set of valid arguments to the ld.

To place the multifile IPO executable in `ipo_file`, use the option `-o filename`, for example:

```
prompt>xild -o ipo_file a.o b.o c.o
```

xild calls Intel compiler to perform IPO for objects containing IR and creates a new list of object(s) to be linked. Then xild calls ld to link the object files that are specified in the new list and produce `ipo_file` executable specified by the `-o filename` option.

**Note**

The `-ipo` option can reorder object files and linker arguments on the command line. Therefore, if your program relies on a precise order of arguments on the command line, `-ipo` can affect the behavior of your program.

**Usage Rules**

You must use the Intel linker `xild` to link your application if:

- Your source files were compiled with multifile IPO enabled. Multifile IPO is enabled by specifying the `-ipo` command-line option
- You normally would invoke the GCC linker (`ld`) to link your application.

**The xild Options**

The additional options supported by xild may be used to examine the results of multifile IPO. These options are described in the following table.
Compilation with Real Object Files

In certain situations you might need to generate real object files with `-ipo`. To force the compiler to produce real object files instead of "mock" ones with IPO, you must specify `-ipo_obj` in addition to `-ipo`.

Use of `-ipo_obj` is necessary under the following conditions:

- The objects produced by the compilation phase of `-ipo` will be placed in a static library without the use of `xiar`. The compiler does not support multifile IPO for static libraries, so all static libraries are passed to the linker. Linking with a static library that contains "mock" object files will result in linkage errors because the objects do not contain real code or data. Specifying `-ipo_obj` causes the compiler to generate object files that can be used in static libraries.

- Alternatively, if you create the static library using `xiar`, then the resulting static library will work as a normal library.

- The objects produced by the compilation phase of `-ipo` might be linked without the `-ipo` option and without the use of `xiar`.

- You want to generate an assembly listing for each source file (using `-S`) while compiling with `-ipo`. If you use `-ipo` with `-S`, but without `-ipo_obj`, the compiler issues a warning and an empty assembly file is produced for each compiled source file.
Creating a Library from IPO Objects

Normally, libraries are created using a library manager such as ar. Given a list of objects, the library manager will insert the objects into a named library to be used in subsequent link steps.

```prompt>xiar cru user.a a.obj b.obj```

The above command creates a library named user.a that contains the a.o and b.o objects.

If, however, the objects have been created using -ipo -c, then the objects will not contain a valid object but only the intermediate representation (IR) for that object file. For example:

```prompt>ifc -ipo -c a.f b.f```

will produce a.o and b.o that only contains IR to be used in a link time compilation. The library manager will not allow these to be inserted in a library.

In this case you must use the Intel library driver xild -ar. This program will invoke the compiler on the IR saved in the object file and generate a valid object that can be inserted in a library.

```prompt>xild -lib cru user.a a.o b.o```

See Creating a Multifile IPO Executable Using xild.

Analyzing the Effects of Multifile IPO, -ipo_c, -ipo_S

The -ipo_c and -ipo_S options are useful for analyzing the effects of multifile IPO, or when experimenting with multifile IPO between modules that do not make up a complete program.

Use the -ipo_c option to optimize across files and produce an object file. This option performs optimizations as described for -ipo, but stops prior to the final link stage, leaving an optimized object file. The default name for this file is ipo_out.o. You can use the -o option to specify a different name. For example:

```prompt>ifc -tpp6 -ipo_c -o filename a.f b.f c.f```

Use the -ipo_S option to optimize across files and produce an assembly file. This option performs optimizations as described for -ipo, but stops prior to the final link stage, leaving an optimized assembly file. The default name for this file is ipo_out.s. You can use the
-o option to specify a different name. For example:

```
prompt> ifc -tpp6 -ipo_S -ofilename a.f b.f c.f
```

For more information on inlining and the minimum inlining criteria, see "Criteria for Inline Function Expansion" and "Controlling Inline Expansion of User Functions."

**Using -ip with -Qoption Specifiers**

You can adjust the Intel® Fortran Compiler’s optimization for a particular application by experimenting with memory and interprocedural optimizations.

Enter the -Qoption option with the applicable keywords to select particular inline expansions and loop optimizations. The option must be entered with a -ip or -ipo specification, as follows:

```
-ip[-Qoption,tool,opts]
```

where tool is Fortran (f) and opts are -Qoption specifiers (see below). Also refer to "Criteria for Inline Function Expansion" to see how these specifiers may affect the inlining heuristics of the compiler.

See "Passing Options to Other Tools (-Qoption,tool,opts)" for details about -Qoption.

**-Qoption Specifiers**

If you specify -ip or -ipo without any -Qoption qualification, the compiler

- expands functions in line
- propagates constant arguments
- passes arguments in registers
- monitors module-level static variables.

You can refine interprocedural optimizations by using the following -Qoption specifiers. To have an effect, the -Qoption option must be entered with either -ip or -ipo also specified, as in this example:

```
-ip -Qoption,f,ip_specifier
```

where ip_specifier is one of the -Qoption specifiers described in the table that follows.
The following command activates procedural and interprocedural optimizations on source.f and sets the maximum increase in the number of intermediate language statements to five for each function:

```bash
prompt> ifc -ip -Qoptionf,-ip_ninl_max_stats=5 source.f
```

### Criteria for Inline Function Expansion

<table>
<thead>
<tr>
<th><strong>-Qoption Specifiers</strong></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ip_args_in_regs=0</td>
<td>Disables the passing of arguments in registers. By default, external functions can pass arguments in registers when called locally. Normally, only static functions can pass arguments in registers, provided the address of the function is not taken and the function does not use a variable number of arguments.</td>
</tr>
<tr>
<td>-ip_ninl_max_stats=n</td>
<td>Sets the valid number of intermediate language statements for a function that is expanded in line. The number n is a positive integer. The number of intermediate language statements usually exceeds the actual number of source language statements. The default value for n is 230.</td>
</tr>
</tbody>
</table>
| -ip_ninl_min_stats=n    | Sets the valid min number of intermediate language statements for a function that is expanded in line. The number n is a positive integer. The default value for ip_ninl_min_stats is:  
  IA-32 compiler: ip_ninl_min_stats = 7  
  Itanium® compiler: ip_ninl_min_stats = 15 |
| -ip_ninl_max_total_stats=n | Sets the maximum increase in size of a function, measured in intermediate language statements, due to inlining. The number n is a positive integer. The default value for n is 2000. |
For a routine to be considered for inlining, it has to meet certain minimum criteria described below.

There are criteria to be met by the call-site, the caller, and the callee. The call-site is the site of the call to the function that might be inlined. The caller is the function that contains the call-site. The callee is the function being called that might be inlined.

**Minimum call-site criteria:**

- The number of actual arguments must match the number of formal arguments of the callee.
- The number of return values must match the number of return values of the callee.
- The data types of the actual and formal arguments must be compatible.
- No multilingual inlining is permitted. Caller and callee must be written in the same source language.

**Minimum criteria for the caller:**

- At most 2000 intermediate statements will be inlined into the caller from all the call-sites being inlined into the caller. You can change this value by specifying the option `-Qoptionf,-ip_inline_max_total_stats=new value`
- The function must be called if it is declared as static. Otherwise, it will be deleted.

**Minimum criteria for the callee:**

- Does not have variable argument list.
- Is not considered infrequent due to the name. Routines which contain the following substrings in their names are not inlined: abort, alloca, denied, err, exit, fail, fatal, fault, halt, init, interrupt, invalid, quit, rare, stop, timeout, trace, trap, and warn.
- Is not considered unsafe for other reasons.

### Selecting Routines for Inlining with or without PGO

Once the above criteria are met, the compiler picks the routines whose inline expansions will provide the greatest benefit to program performance. This is done using the default heuristics. The inlining heuristics used by the compiler differ based on whether you use profile-guided optimizations (`-prof_use`) or not.

**When you use profile-guided optimizations** with `-ip` or `-ipo`, the compiler uses the
following heuristics:

- The default heuristic focuses on the most frequently executed call sites, based on the profile information gathered for the program.

- By default, the compiler does not inline functions with more than 230 intermediate statements. You can change this value by specifying the option -Qoption, ip_ninl_max_stats=new value.

- The default inline heuristic will stop inlining when direct recursion is detected.

- The default heuristic always inlines very small functions that meet the minimum inline criteria.

**Default for Itanium®-based applications:** ip_ninl_min_stats = 15.

**Default for IA-32 applications:** ip_ninl_min_stats = 7.

These limits can be modified with the option -Qoption, ip_ninl_min_stats=new value. See -Qoption Specifiers and Profile-Guided Optimization (PGO).

**When you do not use profile-guided optimizations** with -ip or -ipo, the compiler uses less aggressive inlining heuristics: it inlines a function if the inline expansion does not increase the size of the final program.

### Inlining and Preemption

Preemption of a function means that the code, which implements that function at runtime, is replaced by different code. When a function is preempted, the new version of this function is executed rather than the old version. Preemption can be used to replace an erroneous or inferior version of a function with a correct or improved version.

The compiler assumes that when -ip is on, any externally visible function might be preempted and therefore cannot be inlined. Currently, this means that all Fortran subprograms, except for internal procedures, are not inlinable when -ip is on.

However, if you use -ipo and -ipo_obj on a file-by-file basis, the functions can be inlined. See Compilation with Real Object Files.

### Controlling Inline Expansion of User Functions

The compiler enables you to control the amount of inline function expansion, with the options shown in the following summary.
Inline Expansion of Library Functions

By default, the compiler automatically expands (inlines) a number of standard and math library functions at the point of the call to that function, which usually results in faster computation.

However, the inlined library functions do not set the enerrno variable when being expanded inline. In code that relies upon the setting of the enerrno variable, you should use the -nolib_inline option. Also, if one of your functions has the same name as one of the compiler-supplied library functions, then when this function is called, the compiler assumes that the call is to the library function and replaces the call with an inlined version of the
library function.

So, if the program defines a function with the same name as one of the known library routines, you must use the `-nolib_inline` option to ensure that the user-supplied function is used. 
-`nolib_inline` disables inlining of all intrinsics.

⚠️ **Note**

Automatic inline expansion of library functions is not related to the inline expansion that the compiler does during interprocedural optimizations. For example, the following command compiles the program `sum.f` without expanding the math library functions:

**IA-32 applications:**
```
prompt> ifc -ip -nolib_inline sum.f
```

**Itanium®-based applications:**
```
prompt> efc -ip -nolib_inline sum.f
```

For information on the Intel-provided intrinsic functions, see [Additional Intrinsic Functions](#) in the Reference section.

### Profile-guided Optimizations

Profile-guided optimizations (PGO) tell the compiler which areas of an application are most frequently executed. By knowing these areas, the compiler is able to be more selective and specific in optimizing the application. For example, the use of PGO often enables the compiler to make better decisions about function inlining, thereby increasing the effectiveness of interprocedural optimizations. See [PGO Options summary](#).

### Instrumented Program

Profile-guided Optimization creates an instrumented program from your source code and special code from the compiler. Each time this instrumented code is executed, the instrumented program generates a dynamic information file. When you compile a second time, the dynamic information files are merged into a summary file. Using the profile information in this file, the compiler attempts to optimize the execution of the most heavily travelled paths in the program.

Unlike other optimizations such as those strictly for size or speed, the results of IPO and PGO vary. This is due to each program having a different profile and different opportunities for optimizations. The guidelines provided help you determine if you can benefit by using IPO and PGO. You need to understanding the principles of the optimizations and the unique aspects of your source code.

### Added Performance with PGO

In this version of the Intel® Fortran Compiler, PGO is improved in the following ways:
Register allocation uses the profile information to optimize the location of spill code.

For indirect function calls, branch prediction is improved by identifying the most likely targets. With the Intel® Pentium® 4 and Intel® Xeon(TM) processors' longer pipeline, improving branch prediction translates into high performance gains.

The compiler detects and does not vectorize loops that execute only a small number of iterations, reducing the run time overhead that vectorization might otherwise add.

Profile-guided Optimizations Methodology

PGO works best for code with many frequently executed branches that are difficult to predict at compile time. An example is the code with intensive error-checking in which the error conditions are false most of the time. The "cold" error-handling code can be placed such that the branch is hardly ever mispredicted. Minimizing "cold" code interleaved into the "hot" code improves instruction cache behavior.

PGO Phases

The PGO methodology requires three phases:

1. Instrumentation compilation and linking with `-prof_gen`

2. Instrumented execution by running the executable; as a result, the dynamic-information files (.dyn) are produced.

3. Feedback compilation with `-prof_use`

The flowcharts below illustrate this process for IA-32 compilation and Itanium®-based compilation. A key factor in deciding whether you want to use PGO lies in knowing which sections of your code are the most heavily used. If the data set provided to your program is very consistent and it elicits a similar behavior on every execution, then PGO can probably help optimize your program execution. However, different data sets can elicit different algorithms to be called. This can cause the behavior of your program to vary from one execution to the next.

IA-32 Phases of Basic Profile-Guided Optimization

![Flowchart showing the phases of basic profile-guided optimization for IA-32 compilation](image-url)
Phases of Basic Profile-Guided Optimization for Itanium®-based applications

1. Instrumented Compilation:
   efc -prof_gen a.f

   Output executable files with instrumented code:
   a.out

2. Instrumented Execution:
   a.out

   Output dynamic information files with unique names for each execution:
   $\_\_hex\_digits.dyn$

3. Feedback Compilation:
   efc -prof_use -my_option a.f

   Creates and uses merged dynamic information summary file:
   pgopti.dpi

Profile-Guided Optimized Code
Basic PGO Options

The options used for basic PGO optimizations are:

- `-prof_gen` for generating instrumented code
- `-prof_use` for generating a profile-optimized executable

In cases where your code behavior differs greatly between executions, you have to ensure that the benefit of the profile information is worth the effort required to maintain up-to-date profiles. In the basic profile-guided optimization, the following options are used in the phases of the PGO:

**Generating Instrumented Code, `-prof_gen`**

The `-prof_gen` option instruments the program for profiling to get the execution count of each basic block. It is used in phase 1 of the PGO to instruct the compiler to produce instrumented code in your object files in preparation for instrumented execution. Parallel make is automatically supported for `-prof_gen` compilations.

**Generating a Profile-optimized Executable, `-prof_use`**

The `-prof_use` option is used in phase 3 of the PGO to instruct the compiler to produce a profile-optimized executable and merges available dynamic-information (.dyn) files into a pgopti.dpi file.

⚠️ Note:

The dynamic-information files are produced in phase 2 when you run the instrumented executable.

If you perform multiple executions of the instrumented program, `-prof_use` merges the dynamic-information files again and overwrites the previous pgopti.dpi file.

**Disabling Function Splitting, `-fnsplit` (Itanium® Compiler only)**

`-fnsplit` disables function splitting. Function splitting is enabled by `-prof_use` in phase 3 to improve code locality by splitting routines into different sections: one section to contain the cold or very infrequently executed code and one section to contain the rest of
the code (hot code).

You can use `-fnsplit` to disable function splitting for the following reasons:

- Most importantly, to get improved debugging capability. In the debug symbol table, it is difficult to represent a split routine, that is, a routine with some of its code in the hot code section and some of its code in the cold code section.

The `-fnsplit` option disables the splitting within a routine but enables function grouping, an optimization in which entire routines are placed either in the cold code section or the hot code section. Function grouping does not degrade debugging capability.

- Another reason can arise when the profile data does not represent the actual program behavior, that is, when the routine is actually used frequently rather than infrequently.

⚠️ **Note**
For Itanium®-based applications, if you intend to use the `-prof_use` option with optimizations at the `-O3` level, the `-O3` option must be on. If you intend to use the `-prof_use` option with optimizations at the `-O2` level or lower, you can generate the profile data with the default options.

See [an example of using PGO](#).

### Advanced PGO Options

The options controlling advanced PGO optimizations are:

- `-prof_dir dirname`
- `-prof_file filename`.

#### Specifying the Directory for Dynamic Information Files

Use the `-prof_dir dirname` option to specify the directory in which you intend to place the dynamic information (.dyn) files to be created. The default is the directory where the program is compiled. The specified directory must already exist.

You should specify `-prof_dir dirname` option with the same directory name for both the instrumentation and feedback compilations. If you move the `.dyn` files, you need to specify the new path.

#### Specifying Profiling Summary File
The `-prof_filefilename` option specifies file name for profiling summary file.

**Guidelines for Using Advanced PGO**

When you use PGO, consider the following guidelines:

- Minimize the changes to your program after instrumented execution and before feedback compilation. During feedback compilation, the compiler ignores dynamic information for functions modified after that information was generated.

  ![Note]

  The compiler issues a warning that the dynamic information does not correspond to a modified function.

- Repeat the instrumentation compilation if you make many changes to your source files after execution and before feedback compilation.

- Specify the name of the profile summary file using the `-prof_filefilename` option.

See [PGO Environment Variables](#).

**PGO Environment Variables**

The environment variables determine the directory in which to store dynamic information files or whether to overwrite `pgopti.dpi`. The PGO environment variables are described in the table below.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROF_DIR</td>
<td>Specifies the directory in which dynamic information files are created. This variable applies to all three phases of the profiling process.</td>
</tr>
<tr>
<td>PROF_DUMP_INTERVAL</td>
<td>Initiates interval profile dumping in an instrumented user application.</td>
</tr>
<tr>
<td>PROF_NO_CLOBBER</td>
<td>Alters the feedback compilation phase slightly. By default, during the feedback compilation phase, the compiler merges the data from all dynamic information files and creates a new <code>pgopti.dpi</code> file, even if one already exists. When this variable is set, the compiler does not overwrite the existing <code>pgopti.dpi</code> file. Instead, the compiler issues a warning and you must remove the <code>pgopti.dpi</code> file if you want to use additional dynamic information files.</td>
</tr>
</tbody>
</table>

See also the documentation for your operating system for instructions on how to specify
environment variables and their values.

**Example of Profile-Guided Optimization**

The following is an example of the basic PGO phases:

1. **Instrumentation Compilation and Linking**—Use `-prof_gen` to produce an executable with instrumented information. Use also the `-prof_dir` option as recommended for most programs, especially if the application includes the source files located in multiple directories. `-prof_dir` ensures that the profile information is generated in one consistent place. For example:

   **IA-32 applications:**
   ```
   prompt> ifc -prof_gen -prof_dir/usr/profdata -c a1.f a2.f a3.f
   prompt> ifc -o a1 a1.o a2.o a3.o
   ```

   **Itanium®-based applications:**
   ```
   prompt> efc -prof_gen -prof_dir/usr/profdata -c a1.f a2.f a3.f
   prompt> efc -o a1 a1.o a2.o a3.o
   ```

   In place of the second command, you could use the linker (`ld`) directly to produce the instrumented program. If you do this, make sure you link with the `libirc.a` library.

2. **Instrumented Execution**—Run your instrumented program with a representative set of data to create a dynamic information file.

   ```
   prompt>a1
   ```

   The resulting dynamic information file has a unique name and `.dyn` suffix every time you run `a1`. The instrumented file helps predict how the program runs with a particular set of data. You can run the program more than once with different input data.

3. **Feedback Compilation**—Compile and link the source files with `-prof_use` to use the dynamic information to optimize your program according to its profile:

   **IA-32 applications:**
   ```
   prompt> ifc -prof_use -ipo a1.f a2.f a3.f
   ```

   **Itanium-based applications:**
Besides the optimization, the compiler produces a *pgopti.dpi* file. You typically specify the default optimizations (*-O2*) for phase 1, and specify more advanced optimizations (*-ip* or *-ipo*) for phase 3. This example used *-O2* in phase 1 and the *-ipo* in phase 3.

⚠️ **Note**

The compiler ignores the *-ip* or the *-ipo* options with *-prof_gen*.

See [Basic PGO Options](#).

## Merging the .dyn Files

To merge the .dyn files, use the `profmerge` utility.

### The `profmerge` Utility

The compiler executes `profmerge` automatically during the feedback compilation phase when you specify *-prof_use*.

The command-line usage for `profmerge` is as follows:

**IA-32 applications:**

```
prompt> profmerge [-nologo] [-prof_dir dir_name]
```

**Itanium®-based applications:**

```
prompt> profmerge [-nologo] [-prof_dir dir_name]
```

where `-prof_dir dir_name` is a `profmerge` utility option.

This merges all .dyn files in the current directory or the directory specified by `-prof_dir`, and produces the summary file *pgopti.dpi*.

The `-prof_filename filename` option enables you to specify the name of the .dpi file.

The command-line usage for `profmerge` with `-prof_filename filename` is as follows:

**IA-32 applications:**

```
prompt> profmerge [-nologo] [-prof_filename filename]
```

**Itanium®-based applications:**

```
prompt> profmerge [-nologo] [-prof_filename filename]
```
prompt>profmerge [-nologo] [-prof_filefilename]

where /prof_filefilename is a profmerge utility option.

**Dumping Profile Data**

This subsection provides an example of how to call the C PGO API routines from Fortran. For complete description of the PGO API support routines, see PGO API: Profile Information Generation Support.

As part of the instrumented execution phase of profile-guided optimization, the instrumented program writes profile data to the dynamic information file (.dyn file). The file is written after the instrumented program returns normally from main() or calls the standard exit function. Programs that do not terminate normally, can use the `_PGOPTI_Prof_Dump` function. During the instrumentation compilation (-prof_gen) you can add a call to this function to your program. Here is an example:

```fortran
INTERFACE
SUBROUTINE PGOPTI_PROF_DUMP()
!MS$ATTRIBUTES
C,ALIAS:'PGOPTI_Prof_Dump'::PGOPTI_PROF_DUMP
END SUBROUTINE
END INTERFACE
CALL PGOPTI_PROF_DUMP()
```

⚠️ Note

You must remove the call or comment it out prior to the feedback compilation with -prof_use.

**Using profmerge to Relocate the Source Files**

The compiler uses the full path to the source file for each routine to look up the profile summary information associated with that routine. By default, this prevents you from:

- Using the profile summary file (.dpi) if you move your application sources.
- Sharing the profile summary file with another user who is building identical application sources that are located in a different directory.

**Source Relocation**

To enable the movement of application sources, as well as the sharing of profile summary files, use the profmerge with -src_old and -src_new options. For example:
prompt> profmerge -prof_dir c:/work -src_old c:/work/sources -src_new d:/project/src

The above command will read the c:/work/pgopti.dpi file. For each routine represented in the pgopti.dpi file, whose source path begins with the c:/work/sources prefix, profmerge replaces that prefix with d:/project/src. The c:/work/pgopti.dpi file is updated with the new source path information.

Notes

- You can execute profmerge more than once on a given pgopti.dpi file. You may need to do this if the source files are located in multiple directories. For example:

  profmerge -src_old "c:/program files" -src_new "e:/program files"

  profmerge -src_old c:/proj/application -src_new d:/app

- In the values specified for -src_old and -src_new, uppercase and lowercase characters are treated as identical. Likewise, forward slash (/) and backward slash (\) characters are treated as identical.

- Because the source relocation feature of profmerge modifies the pgopti.dpi file, you may wish to make a backup copy of the file prior to performing the source relocation.

PGO API Support Overview

The Profile Information Generation Support (Profile IGS) enables you to control the generation of profile information during the instrumented execution phase of profile-guided optimizations.

Normally, profile information is generated by an instrumented application when it terminates by calling the standard exit() function.

To ensure that profile information is generated, the functions described in this section may be necessary or useful in the following situations:

- The instrumented application exits using a non-standard exit routine.
- The instrumented application is a non-terminating application: exit() is never called.
- The application requires control of when the profile information is generated.
A set of functions and an environment variable comprise the Profile IGS.

**The Profile IGS Functions**

The Profile IGS functions are available to your application by inserting a header file at the top of any source file where the functions may be used.

```c
#include "pgouser.h"
```

**Note**
The Profile IGS functions are written in C language. Fortran applications need to call C functions.

The rest of the topics in this section describe the Profile IGS functions.

**Note**
Without instrumentation, the Profile IGS functions cannot provide PGO API support.

**The Profile IGS Environment Variable**

The environment variable for Profile IGS is `PROF_DUMP_INTERVAL`. This environment variable may be used to initiate Interval Profile Dumping in an instrumented user application. See the recommended usage of `_PGOPTI_Set_Interval_Prof_Dump()` for more information.

**Dumping Profile Information**

The `_PGOPTI_Prof_Dump()` function dumps the profile information collected by the instrumented application and has the following prototype:

```c
void _PGOPTI_Prof_Dump(void);
```

The profile information is generated in a `.dyn` file (generated in phase 2 of the PGO).

**Recommended usage**

Insert a single call to this function in the body of the function which terminates the user application. Normally, `_PGOPTI_Prof_Dump()` should be called just once.

It is also possible to use this function in conjunction with the `_PGOPTI_Prof_Reset()` function to generate multiple `.dyn` files (presumably from multiple sets of input data).
Resetting the Dynamic Profile Counters

The _PGOPTI_Prof_Reset() function resets the dynamic profile counters and has the following prototype:

```c
void _PGOPTI_Prof_Reset(void);
```

**Recommended usage**

Use this function to clear the profile counters prior to collecting profile information on a section of the instrumented application. See the example under _PGOPTI_Prof_Dump()_.

Dumping and Resetting Profile Information

The _PGOPTI_Prof_Dump_And_Reset() function dumps the profile information to a new .dyn file and then resets the dynamic profile counters. Then the execution of the instrumented application continues. The prototype of this function is:

```c
void _PGOPTI_Prof_Dump_And_Reset(void);
```

This function is used in non-terminating applications and may be called more than once.

**Recommended usage**
Periodic calls to this function enables a non-terminating application to generate one or more profile information files (.dyn files). These files are merged during the feedback phase (phase 3) of profile-guided optimizations. The direct use of this function enables your application to control precisely when the profile information is generated.

**Interval Profile Dumping**

The `_PGOPTI_Set_Interval_Prof_Dump()` function activates Interval Profile Dumping and sets the approximate frequency at which dumps occur. The prototype of the function call is:

```c
void _PGOPTI_Set_Interval_Prof_Dump(int interval);
```

This function is used in non-terminating applications.

The `interval` parameter specifies the time interval at which profile dumping occurs and is measured in milliseconds. For example, if interval is set to 5000, then a profile dump and reset will occur approximately every 5 seconds. The interval is approximate because the time-check controlling the dump and reset is only performed upon entry to any instrumented function in your application.

**Notes**

1. Setting interval to zero or a negative number will disable interval profile dumping.

2. Setting a very small value for interval may cause the instrumented application to spend nearly all of its time dumping profile information. Be sure to set interval to a large enough value so that the application can perform actual work and substantial profile information is collected.

**Recommended usage**

This function may be called at the start of a non-terminating user application, to initiate Interval Profile Dumping. Note that an alternative method of initiating Interval Profile Dumping is by setting the environment variable, `PROF_DUMP_INTERVAL`, to the desired interval value prior to starting the application.

The intention of Interval Profile Dumping is to allow a non-terminating application to be profiled with minimal changes to the application source code.

**High-Level Optimizations**

High-level optimizations exploit the properties of source code constructs (for example, loops and arrays) in the applications developed in high-level programming languages, such as Fortran and C++. The high-level optimizations include loop interchange, loop fusion, loop
unrolling, loop distribution, unroll-and-jam, blocking, data prefetch, scalar replacement, data layout optimizations and loop unrolling techniques.

The option that turns on the high-level optimizations is -O3. See high-level language options summary. The scope of optimizations turned on by -O3 is different for IA-32 and Itanium®-based applications. See Setting Optimization Levels.

<table>
<thead>
<tr>
<th>IA-32 and Itanium®-based applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>-O3</td>
</tr>
<tr>
<td>Enable -O2 option plus more aggressive optimizations, for example, loop transformation and prefetching. -O3 optimizes for maximum speed, but may not improve performance for some programs.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IA-32 applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>-O3</td>
</tr>
<tr>
<td>In addition, in conjunction with the vectorization options, -ax{M</td>
</tr>
</tbody>
</table>

**Loop Transformations**

The loop transformation techniques include:

- loop normalization
- loop reversal
- loop interchange and permutation
- loop skewing
- loop distribution
- loop fusion
- scalar replacement

The loop transformations listed above are supported by data dependence. The loop transformation techniques also include:
- induction variable elimination
- constant propagation
- copy propagation
- forward substitution
- and dead code elimination.

In addition to the loop transformations listed for both IA-32 and Itanium® architectures above, the Itanium architecture enables implementation of the collapsing techniques.

**Scalar Replacement (IA-32 Only)**

The goal of scalar replacement is to reduce memory references. This is done mainly by replacing array references with register references.

While the compiler replaces some array references with register references when `-O1` or `-O2` is specified, more aggressive replacement is performed when `-O3 (-scalar_rep)` is specified. For example, with `-O3` the compiler attempts replacement when there are loop-carried dependences or when data-dependence analysis is required for memory disambiguation.

| `-scalar_rep[-]` | Enables (default) or disables scalar replacement performed during loop transformations (requires `-O3`). |

**Loop Unrolling with `-unroll [n]`**

The `-unroll [n]` option is used in the following way:

- `-unroll n` specifies the maximum number of times you want to unroll a loop. The following example unrolls a loop at most four times:

  ```fortran
  prompt> ifc -unroll4 a.f
  ```

  To disable loop unrolling, specify `n` as 0. The following example disables loop unrolling:

  ```fortran
  prompt> ifc -unroll0 a.f
  ```

  - `-unroll (n omitted)` lets the compiler decide whether to perform unrolling or not.
- **-unroll0 \( (n = 0) \)** disables unroller.

Itanium® compiler currently uses only \( n = 0; \) any other value is NOP.

**Benefits and Limitations of Loop Unrolling**

The benefits are:

- Unrolling eliminates branches and some of the code.
- Unrolling enables you to aggressively schedule (or pipeline) the loop to hide latencies if you have enough free registers to keep variables live.
- The Intel® Pentium® 4 or Intel® Xeon (TM) processors can correctly predict the exit branch for an inner loop that has 16 or fewer iterations, if that number of iterations is predictable and there are no conditional branches in the loop. Therefore, if the loop body size is not excessive, and the probable number of iterations is known, unroll inner loops for:
  - Pentium 4 or Intel Xeon processor, until they have a maximum of 16 iterations
  - Pentium III or Pentium II processors, until they have a maximum of 4 iterations

The potential costs are:

- Excessive unrolling, or unrolling of very large loops can lead to increased code size.
- If the number of iterations of the unrolled loop is 16 or less, the branch predictor should be able to correctly predict branches in the loop body that alternate direction.

For more information on how to optimize with `-unroll [n]`, refer to *Intel® Pentium® 4 and Intel® Xeon(TM) Processor Optimization Reference Manual*.

**Memory Dependency with IVDEP Directive**

The `-ivdep_parallel` option discussed below is used for Itanium®-based applications only.

The `-ivdep_parallel` option indicates there is absolutely no loop-carried memory dependency in the loop where IVDEP directive is specified. This technique is useful for some sparse matrix applications.

For example, the following loop requires `-ivdep_parallel` in addition to the directive IVDEP to indicate there is no loop-carried dependencies.
The following example shows that using this option and the IVDEP directive ensures there is no loop-carried dependency for the store into a().

```
!DIR$IVDEP
do i=1,n
e(ix(2,i))=e(ix(2,i))+1.0
e(ix(3,i))=e(ix(3,i))+2.0
enddo
```

The following example shows that using this option and the IVDEP directive ensures there is no loop-carried dependency for the store into a().

```
!DIR$IVDEP
do j=1,n
a(b(j)) = a(b(j))+1
enddo
```

See IVDEP directive for IA-32 applications.

### Prefetching

The goal of -prefetch insertion is to reduce cache misses by providing hints to the processor about when data should be loaded into the cache. The prefetching optimizations implement the following options:

<table>
<thead>
<tr>
<th>-prefetch [-]</th>
<th>Enable or disable (-prefetch-) prefetch insertion. This option requires that -O3 be specified. The default with -O3 is -prefetch.</th>
</tr>
</thead>
</table>

To facilitate compiler optimization:

- Minimize use of global variables and pointers.
- Minimize use of complex control flow.
- Choose data types carefully and avoid type casting.

For more information on how to optimize with -prefetch [-], refer to Intel® Pentium® 4 and Intel® Xeon(TM) Processor Optimization Reference Manual.

### Parallelization

For shared memory parallel programming, the Intel® Fortran Compiler supports both the OpenMP® API and an automatic parallelization capability.

The compiler supports the OpenMP Fortran version 2.0 API specification and provides symmetric multiprocessing (SMP), which relieves the user from having to deal with the low-
level details of iteration space partitioning, data sharing, and thread scheduling and synchronization; it also provides the performance gain from shared memory, multiprocessor systems.

The auto-parallelization feature of the Intel Fortran Compiler automatically translates serial portions of the input program into equivalent multithreaded code. Automatic parallelization determines the loops that are good worksharing candidates, performs the dataflow analysis to verify correct parallel execution, and partitions the data for threaded code generation as is needed in programming with OpenMP directives.

The following table lists the options that perform OpenMP and auto-parallelization support.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-openmp</td>
<td>Enables the parallelizer to generate multithreaded code based on the OpenMP directives. Default: OFF.</td>
</tr>
<tr>
<td>-openmp_report{0</td>
<td>1</td>
</tr>
<tr>
<td>-openmp_stubs</td>
<td>Enables compilation of OpenMP programs in sequential mode. The OpenMP directives are ignored and a stub OpenMP library is linked. Default: OFF.</td>
</tr>
<tr>
<td>-parallel</td>
<td>Enables the auto-parallelizer to generate multithreaded code for loops that can be safely executed in parallel. Default: OFF.</td>
</tr>
<tr>
<td>-par_threshold{n}</td>
<td>Sets a threshold for the auto-parallelization of loops based on the probability of profitable execution of the loop in parallel, n=0 to 100. n=0 implies &quot;always.&quot; Default: n=75.</td>
</tr>
<tr>
<td>-par_report{0</td>
<td>1</td>
</tr>
</tbody>
</table>

$pdf$ Note

When both -openmp and -parallel are specified on the command line, the -parallel option is only honored in routines that do not contain OpenMP directives. For routines that contain OpenMP directives, only the -openmp option is honored.

Important component of the parallelization programming is the Intel Fortran Compiler's vectorizer. The vectorizer detects operations in the program that can be done in parallel, and then converts the sequential program to process 2, 4, 8 or up to 16 elements in one operation, depending on the data type. In some cases auto-parallelization and vectorization can be combined for better performance results.

Parallelization with OpenMP* Overview
The Intel® Fortran Compiler supports the OpenMP® Fortran version 2.0 API specification. OpenMP provides symmetric multiprocessing (SMP) with the following major features:

- Relieves the user from having to deal with the low-level details of iteration space partitioning, data sharing, and thread scheduling and synchronization.
- Provides the benefit of the performance available from shared memory, multiprocessor systems.

The Intel Fortran Compiler performs transformations to generate multithreaded code based on the user's placement of OpenMP directives in the source program making it easy to add threading to existing software. The Intel compiler supports all of the current industry-standard OpenMP directives, except workshare, and compiles parallel programs annotated with OpenMP directives.

In addition, the Intel Fortran Compiler provides Intel-specific extensions to the OpenMP Fortran version 2.0 specification including runtime library routines and environment variables.

⚠️ Note

As with many advanced features of compilers, you must properly understand the functionality of the OpenMP directives in order to use them effectively and avoid unwanted program behavior.

See parallelization options summary for all options of the OpenMP feature in the Intel Fortran Compiler. For complete information on the OpenMP standard, visit the www.openmp.org web site. For complete Fortran language specifications, see the OpenMP Fortran version 2.0 specifications.

**Parallel Processing with OpenMP**

To compile with OpenMP, you need to prepare your program by annotating the code with OpenMP directives in the form of the Fortran program comments. The Intel Fortran Compiler first processes the application and produces a multithreaded version of the code which is then compiled. The output is a Fortran executable with the parallelism implemented by threads that execute parallel regions or constructs. See Programming with OpenMP.

**Performance Analysis**

For performance analysis of your program, you can use the VTune(TM) analyzer to show performance information. You can obtain detailed information about which portions of the code that require the largest amount of time to execute and where parallel performance problems are located.
Programming with OpenMP

The Intel® Fortran Compiler accepts a Fortran program containing OpenMP directives as input and produces a multithreaded version of the code. When the parallel program begins execution, a single thread exists. This thread is called the master thread. The master thread will continue to process serially until it encounters a parallel region.

Parallel Region

A parallel region is a block of code that must be executed by a team of threads in parallel. In the OpenMP Fortran API, a parallel construct is defined by placing OpenMP directives `parallel` at the beginning and `end parallel` at the end of the code segment. Code segments thus bounded can be executed in parallel.

A structured block of code is a collection of one or more executable statements with a single point of entry at the top and a single point of exit at the bottom.

The Intel Fortran Compiler supports worksharing and synchronization constructs. Each of these constructs consists of one or two specific OpenMP directives and sometimes the enclosed or following structured block of code. For complete definitions of constructs, see the OpenMP Fortran version 2.0 specifications.

At the end of the parallel region, threads wait until all team members have arrived. The team is logically disbanded (but may be reused in the next parallel region), and the master thread continues serial execution until it encounters the next parallel region.

Worksharing Construct

A worksharing construct divides the execution of the enclosed code region among the members of the team created on entering the enclosing parallel region. When the master thread enters a parallel region, a team of threads is formed. Starting from the beginning of the parallel region, code is replicated (executed by all team members) until a worksharing construct is encountered. A worksharing construct divides the execution of the enclosed code among the members of the team that encounter it.

The OpenMP sections or do constructs are defined as worksharing constructs because they distribute the enclosed work among the threads of the current team. A worksharing construct is only distributed if it is encountered during dynamic execution of a parallel region. If the worksharing construct occurs lexically inside of the parallel region, then it is always executed by distributing the work among the team members. If the worksharing construct is not lexically (explicitly) enclosed by a parallel region (that is, it is orphaned), then the worksharing construct will be distributed among the team members of the closest dynamically-enclosing parallel region, if one exists. Otherwise, it will be executed serially.

When a thread reaches the end of a worksharing construct, it may wait until all team
members within that construct have completed their work. When all of the work defined by the worksharing construct is finished, the team exits the worksharing construct and continues executing the code that follows.

A combined parallel/worksharing construct denotes a parallel region that contains only one worksharing construct.

**Parallel Processing Directive Groups**

The parallel processing directives include the following groups:

**Parallel Region**

- PARALLEL and END PARALLEL

**Worksharing Construct**

- The DO and END DO directives specify parallel execution of loop iterations.

- The SECTIONS and END SECTIONS directives specify parallel execution for arbitrary blocks of sequential code. Each SECTION is executed once by a thread in the team.

- The SINGLE and END SINGLE directives define a section of code where exactly one thread is allowed to execute the code; threads not chosen to execute this section ignore the code.

**Combined Parallel/Worksharing Constructs**

The combined parallel/worksharing constructs provide an abbreviated way to specify a parallel region that contains a single worksharing construct. The combined parallel/worksharing constructs are:

- PARALLEL DO and END PARALLEL DO

- PARALLEL SECTIONS and END PARALLEL SECTIONS

**Synchronization and MASTER**

Synchronization is the interthread communication that ensures the consistency of shared data and coordinates parallel execution among threads. Shared data is consistent within a team of threads when all threads obtain the identical value when the data is accessed. A synchronization construct is used to insure this consistency of the shared data.

- The OpenMP synchronization directives are CRITICAL, ORDERED, ATOMIC, FLUSH, and BARRIER.
  
  o Within a parallel region or a worksharing construct only one thread at a
time is allowed to execute the code within a CRITICAL construct.

- The ORDERED directive is used in conjunction with a DO or SECTIONS construct to impose a serial order on the execution of a section of code.

- The ATOMIC directive is used to update a memory location in an uninterruptable fashion.

- The FLUSH directive is used to insure that all threads in a team have a consistent view of memory.

- A BARRIER directive forces all team members to gather at a particular point in code. Each team member that executes a BARRIER waits at the BARRIER until all of the team members have arrived. A BARRIER cannot be used within worksharing or other synchronization constructs due to the potential for deadlock.

- The MASTER directive is used to force execution by the master thread.

See the list of OpenMP Directives and Clauses.

**Data Sharing**

Data sharing is specified at the start of a parallel region or worksharing construct by using the shared and private clauses. All variables in the shared clause are shared among the members of a team. It is the application’s responsibility to:

- synchronize access to these variables. All variables in the private clause are private to each team member. For the entire parallel region, assuming \( t \) team members, there are \( t+1 \) copies of all the variables in the private clause: one global copy that is active outside parallel regions and a private copy for each team member.

- initialize private variables at the start of a parallel region, unless the firstprivate clause is specified. In this case, the private copy is initialized from the global copy at the start of the construct at which the firstprivate clause is specified.

- update the global copy of a private variable at the end of a parallel region. However, the lastprivate clause of a DO directive enables updating the global copy from the team member that executed serially the last iteration of the loop.

In addition to shared and private variables, individual variables and entire common blocks can be privatized using the threadprivate directive.

**Orphaned Directives**
OpenMP contains a feature called orphaning which dramatically increases the expressiveness of parallel directives. Orphaning is a situation when directives related to a parallel region are not required to occur lexically within a single program unit. Directives such as critical, barrier, sections, single, master, and do, can occur by themselves in a program unit, dynamically “binding” to the enclosing parallel region at run time.

Orphaned directives enable parallelism to be inserted into existing code with a minimum of code restructuring. Orphaning can also improve performance by enabling a single parallel region to bind with multiple do directives located within called subroutines. Consider the following code segment:

```fortran
... !$omp parallel
call phase1
call phase2
$omp end parallel ...

subroutine phase1
$omp do private(i)
shared(n)
do i = 1, n
call some_work(i)
end do
$omp end do
end subroutine phase1

subroutine phase2
$omp do private(j)
shared(n)
do j = 1, n
call more_work(j)
end do
$omp end do
end subroutine phase2
```

**Orphaned Directives Usage Rules**

- An orphaned worksharing construct (section, single, do) is executed by a team consisting of one thread, that is, serially.

- Any collective operation (worksharing construct or barrier) executed inside of a worksharing construct is illegal.

- It is illegal to execute a collective operation (worksharing construct or barrier) from within a synchronization region (critical/ordered).
• The opening and closing directives of a directive pair (for example, `do` `end do`) must occur in a single block of the program.

• Private scoping of a variable can be specified at a worksharing construct. Shared scoping must be specified at the parallel region. For complete details, see the OpenMP Fortran version 2.0 specifications.

Preparing Code for OpenMP Processing

The following are the major stages and steps of preparing your code for using OpenMP. Typically, the first two stages can be done on uniprocessor or multiprocessor systems; later stages are typically done only on multiprocessor systems.

Before Inserting OpenMP Directives

Before inserting any OpenMP parallel directives, verify that your code is safe for parallel execution by doing the following:

• Place local variables on the stack. This is the default behavior of the Intel Fortran Compiler when `-openmp` is used.

• Use `-auto` or similar (`-auto_scalar`) compiler option to make the locals automatic. Avoid using compiler options that inhibit stack allocation of local variables. By default (`-auto_scalar`) local scalar variables become shared across threads, so you may need to add synchronization code to ensure proper access by threads.

Analyze

The analysis includes the following major actions:

• Profile the program to find out where it spends most of its time. This is the part of the program that benefits most from parallelization efforts. This stage can be accomplished using basic PGO options.

• Wherever the program contains nested loops, choose the outer-most loop, which has very few cross-iteration dependencies.

• Restructure

• To restructure your program for successful OpenMP implementation, you can perform some or all of the following actions:

  1. If a chosen loop is able to execute iterations in parallel, introduce a parallel do construct around this loop.

  2. Try to remove any cross-iteration dependencies by rewriting the algorithm.
3. Synchronize the remaining cross-iteration dependencies by placing critical constructs around the uses and assignments to variables involved in the dependencies.

4. List the variables that are present in the loop within appropriate shared, private, lastprivate, firstprivate, or reduction clauses.

5. List the do index of the parallel loop as private. This step is optional.

6. common block elements must not be placed on the private list if their global scope is to be preserved. The threadprivate directive can be used to privatize to each thread the common block containing those variables with global scope. threadprivate creates a copy of the common block for each of the threads in the team.

7. Any I/O in the parallel region should be synchronized.

8. Identify more parallel loops and restructure them.

9. If possible, merge adjacent parallel do constructs into a single parallel region containing multiple do directives to reduce execution overhead.

**Tune**

The tuning process should include minimizing the sequential code in critical sections and load balancing by using the schedule clause or the omp_schedule environment variable.

⚠️ **Note**

This step is typically performed on a multiprocessor system.

---

**Parallel Processing Thread Model**

This topic explains the processing of the parallelized program and adds more definitions of the terms used in the parallel programming.

**The Execution Flow**

As mentioned in previous topic, a program containing OpenMP Fortran API compiler directives begins execution as a single process, called the master thread of execution. The master thread executes sequentially until the first parallel construct is encountered.
In OpenMP Fortran API, the `PARALLEL` and `END PARALLEL` directives define the parallel construct. When the master thread encounters a parallel construct, it creates a team of threads, with the master thread becoming the master of the team. The program statements enclosed by the parallel construct are executed in parallel by each thread in the team. These statements include routines called from within the enclosed statements.

The statements enclosed lexically within a construct define the static extent of the construct. The dynamic extent includes the static extent as well as the routines called from within the construct. When the `END PARALLEL` directive is encountered, the threads in the team synchronize at that point, the team is dissolved, and only the master thread continues execution. The other threads in the team enter a wait state.

You can specify any number of parallel constructs in a single program. As a result, thread teams can be created and dissolved many times during program execution.

**Using Orphaned Directives**

In routines called from within parallel constructs, you can also use directives. Directives that are not in the lexical extent of the parallel construct, but are in the dynamic extent, are called orphaned directives. Orphaned directives allow you to execute major portions of your program in parallel with only minimal changes to the sequential version of the program. Using this functionality, you can code parallel constructs at the top levels of your program call tree and use directives to control execution in any of the called routines. For example:

```fortran
subroutine F
...
$OMP parallel...
...
  call G
...
subroutine G
...
$OMP DO...
...
```

The `!$OMP DO` is an orphaned directive because the parallel region it will execute in is not lexically present in `G`.

**Data Environment Directive**

A data environment directive controls the data environment during the execution of parallel constructs.

You can control the data environment within parallel and worksharing constructs. Using directives and data environment clauses on directives, you can:

- Privatize named common blocks by using `THREADPRIVATE` directive
Control data scope attributes by using the \texttt{THREADPRIVATE} directive's clauses.

The data scope attribute clauses are:

- \texttt{COPYIN}
- \texttt{DEFAULT}
- \texttt{PRIVATE}
- \texttt{FIRSTPRIVATE}
- \texttt{LASTPRIVATE}
- \texttt{REDUCTION}
- \texttt{SHARED}

You can use several directive clauses to control the data scope attributes of variables for the duration of the construct in which you specify them. If you do not specify a data scope attribute clause on a directive, the default is \texttt{SHARED} for those variables affected by the directive.

For detailed descriptions of the clauses, see the OpenMP Fortran version 2.0 specifications.

**Pseudo Code of the Parallel Processing Model**

A sample program using some of the more common OpenMP directives is shown in the code example that follows. This example also indicates the difference between serial regions and parallel regions.

```fortran
program main  ! Begin Serial Execution
  ...
  ! Only the master thread executes
  !$omp parallel  ! Begin a Parallel Construct, form a team
  ...
  ! This is Replicated Code where each team member executes the same code
  !$omp sections  ! Begin a Worksharing Construct
  !$omp section   ! One unit of work
  ...
  !$omp section   ! Another unit of work
  ...
```
To run the Intel® Fortran Compiler in OpenMP mode, you need to invoke the Intel compiler with the
\texttt{-openmp} option:

\texttt{ia-32 applications:}

\texttt{ifc -openmp \texttt{input\_file(s)}}

\texttt{itanium\textregistered-based applications:}

\texttt{efc -openmp \texttt{input\_file(s)}}

Before you run the multithreaded code, you can set the number of desired threads to the OpenMP environment variable, \texttt{OMP\_NUM\_THREADS}. See the \texttt{OpenMP Environment Variables} section for further information. The \texttt{Intel Extension Routines} topic describes the OpenMP extensions to the specification that have been added by Intel in the Intel® Fortran Compiler.

\textbf{\texttt{-openmp Option}}

The \texttt{-openmp} option enables the parallelizer to generate multithreaded code based on

\begin{verbatim}
!$omp end ! Wait until both units of work
sections complete
...
! More Replicated Code
!$omp do ! Begin a Worksharing
Construct,
do ! each iteration is a unit of
work
...
! Work is distributed among the
team
end do !
!$omp end do ! End of Worksharing Construct,
nowait nowait is
! specified
...
! More Replicated Code
!$omp end ! End of Parallel Construct,
parallel disband team ! and continue
with serial execution
...
! Possibly more Parallel
Constructs
end ! End serial execution
\end{verbatim}
the OpenMP directives. The code can be executed in parallel on both uniprocessor and multiprocessor systems.

The \texttt{-openmp} option works with both \texttt{-O0} (no optimization) and any optimization level of \texttt{-O1}, \texttt{-O2} (default) and \texttt{-O3}. Specifying \texttt{-O0} with \texttt{-openmp} helps to debug OpenMP applications.

When you use the \texttt{-openmp} option, the compiler sets the \texttt{-auto option} (causes all variables to be allocated on the stack, rather than in local static storage.) for the compiler unless you specified it on the command line.

### OpenMP Directive Format and Syntax

The OpenMP directives use the following format:

\[
\texttt{<prefix> <directive> [\texttt{<clause> [[,] <clause> . . .]]}}
\]

where the brackets above mean:

- \texttt{<xxx>}: the prefix and directive are required
- \texttt{[<xxx>]}: if a directive uses one clause or more, the clause(s) is required
- \texttt{[,]}: commas between the \texttt{<clause>}s are optional.

**For fixed form** source input, the prefix is \texttt{!$omp} or \texttt{c$omp}

**For free form** source input, the prefix is \texttt{!$omp} only.

The prefix is followed by the directive name; for example:

\texttt{!$omp parallel}

Since OpenMP directives begin with an exclamation point, the directives take the form of comments if you omit the \texttt{-openmp} option.

### Syntax for Parallel Regions in the Source Code

The OpenMP constructs defining a parallel region have one of the following syntax forms:

\texttt{!$omp <directive>}

\texttt{<structured block of code>}

\texttt{!$omp end <directive>}

or
!$omp <directive>
<structured block of code>
or
!$omp <directive>

where <directive> is the name of a particular OpenMP directive.

**OpenMP Diagnostics**

The `-openmp_report{0|1|2}` option controls the OpenMP parallelizer's diagnostic levels 0, 1, or 2 as follows:

- `-openmp_report0` = no diagnostic information is displayed.
- `-openmp_report1` = display diagnostics indicating loops, regions, and sections successfully parallelized.
- `-openmp_report2` = same as `-openmp_report1` plus diagnostics indicating master constructs, single constructs, critical constructs, ordered constructs, atomic directives, etc. successfully handled.

The default is `-openmp_report1`.

**OpenMP Directives and Clauses Summary**

This topic provides a summary of the OpenMP directives and clauses. For detailed descriptions, see the [OpenMP Fortran version 2.0 specifications](#).

**OpenMP Directives**

<table>
<thead>
<tr>
<th>Directive</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>parallel</code></td>
<td>Defines a parallel region.</td>
</tr>
<tr>
<td><code>end parallel</code></td>
<td></td>
</tr>
<tr>
<td><code>do</code></td>
<td>Identifies an iterative worksharing construct in which the iterations of the</td>
</tr>
<tr>
<td><code>end do</code></td>
<td>associated loop should be executed in parallel.</td>
</tr>
<tr>
<td><code>sections</code></td>
<td>Identifies a non-iterative worksharing construct that specifies a set of</td>
</tr>
<tr>
<td><code>end sections</code></td>
<td>structured blocks that are to be divided among threads in a team.</td>
</tr>
<tr>
<td>section</td>
<td>Indicates that the associated structured block should be executed in parallel as part of the enclosing sections construct.</td>
</tr>
<tr>
<td>---------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>single</td>
<td>Identifies a construct that specifies that the associated structured block is executed by only one thread in the team.</td>
</tr>
<tr>
<td>end single</td>
<td></td>
</tr>
<tr>
<td>parallel do</td>
<td>A shortcut for a parallel region that contains a single do directive.</td>
</tr>
<tr>
<td>do</td>
<td></td>
</tr>
<tr>
<td>parallel</td>
<td>Provides a shortcut form for specifying a parallel region containing a single sections construct.</td>
</tr>
<tr>
<td>sections</td>
<td></td>
</tr>
<tr>
<td>end parallel sections</td>
<td></td>
</tr>
<tr>
<td>master</td>
<td>Identifies a construct that specifies a structured block that is executed by only the master thread of the team.</td>
</tr>
<tr>
<td>end master</td>
<td></td>
</tr>
<tr>
<td>critical</td>
<td>Identifies a construct that restricts execution of the associated structured block to a single thread at a time. Each thread waits at the beginning of the critical construct until no other thread is executing a critical construct with the same lock argument.</td>
</tr>
<tr>
<td>[lock]</td>
<td></td>
</tr>
<tr>
<td>end critical</td>
<td></td>
</tr>
<tr>
<td>[lock]</td>
<td></td>
</tr>
<tr>
<td>barrier</td>
<td>Synchronizes all the threads in a team. Each thread waits until all of the other threads in that team have reached this point.</td>
</tr>
<tr>
<td>atomic</td>
<td>Ensures that a specific memory location is updated atomically, rather than exposing it to the possibility of multiple, simultaneously writing threads.</td>
</tr>
<tr>
<td>flush</td>
<td>Specifies a &quot;cross-thread&quot; sequence point at which the implementation is required to ensure that all the threads in a team have a consistent view of certain objects in memory. The optional list argument consists of a comma-separated list of variables to be flushed.</td>
</tr>
<tr>
<td>[(list)]</td>
<td></td>
</tr>
<tr>
<td>ordered</td>
<td>The structured block following an ordered directive is executed in the order in which iterations would be executed in a sequential loop.</td>
</tr>
<tr>
<td>end ordered</td>
<td></td>
</tr>
<tr>
<td>threadprivate</td>
<td>Makes the named common blocks or variables private to a thread. The list argument consists of a comma-separated list of common blocks or variables.</td>
</tr>
<tr>
<td>(list)</td>
<td></td>
</tr>
</tbody>
</table>
## OpenMP Clauses

<table>
<thead>
<tr>
<th>Clause</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>private (list)</td>
<td>Declares variables in list to be private to each thread in a team.</td>
</tr>
<tr>
<td>firstprivate (list)</td>
<td>Same as private, but the copy of each variable in the list is initialized using the value of the original variable existing before the construct.</td>
</tr>
<tr>
<td>lastprivate (list)</td>
<td>Same as private, but the original variables in list are updated using the values assigned to the corresponding private variables in the last iteration in the do construct loop or the last section construct.</td>
</tr>
<tr>
<td>copyprivate (list)</td>
<td>Uses private variables in list to broadcast values, or pointers to shared objects, from one member of a team to the other members at the end of a single construct.</td>
</tr>
<tr>
<td>nowait</td>
<td>Specifies that threads need not wait at the end of worksharing constructs until they have completed execution. The threads may proceed past the end of the worksharing constructs as soon as there is no more work available for them to execute.</td>
</tr>
<tr>
<td>shared (list)</td>
<td>Shares variables in list among all the threads in a team.</td>
</tr>
<tr>
<td>default (mode)</td>
<td>Determines the default data-scope attributes of variables not explicitly specified by another clause. Possible values for mode are private, shared, or none.</td>
</tr>
<tr>
<td>reduction (operator</td>
<td>intrinsic):list)</td>
</tr>
<tr>
<td>Clause</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>ordered end ordered</td>
<td>Used in conjunction with a <code>do</code> or <code>sections</code> construct to impose a serial order on the execution of a section of code. If <code>ordered</code> constructs are contained in the dynamic extent of the <code>do</code> construct, the <code>ordered</code> clause must be present on the <code>do</code> directive.</td>
</tr>
<tr>
<td>if (scalar_logical_expression)</td>
<td>The enclosed parallel region is executed in parallel only if the <code>scalar_logical_expression</code> evaluates to <code>.true.</code>; otherwise the parallel region is serialized.</td>
</tr>
<tr>
<td>num_threads (scalar_integer_expression)</td>
<td>Requests the number of threads specified by <code>scalar_integer_expression</code> for the parallel region.</td>
</tr>
<tr>
<td>schedule (type[,chunk])</td>
<td>Specifies how iterations of the <code>do</code> construct are divided among the threads of the team. Possible values for the <code>type</code> argument are static, dynamic, guided, and runtime. The optional <code>chunk</code> argument must be a positive scalar integer expression.</td>
</tr>
<tr>
<td>copyin (list)</td>
<td>Specifies that the master thread's data values be copied to the threadprivate's copies of the common blocks or variables specified in <code>list</code> at the beginning of the parallel region.</td>
</tr>
</tbody>
</table>

### Directives and Clauses Cross-reference

<table>
<thead>
<tr>
<th>Directive</th>
<th>Uses These Clauses</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARALLEL</td>
<td>COPYIN, DEFAULT, PRIVATE, FIRSTPRIVATE, REDUCTION, SHARED</td>
</tr>
<tr>
<td>END PARALLEL</td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>PRIVATE, FIRSTPRIVATE, LASTPRIVATE, REDUCTION, SCHEDULE</td>
</tr>
<tr>
<td>END DO</td>
<td></td>
</tr>
<tr>
<td>SECTIONS</td>
<td>PRIVATE, FIRSTPRIVATE, LASTPRIVATE, REDUCTION</td>
</tr>
<tr>
<td>END SECTIONS</td>
<td></td>
</tr>
<tr>
<td>SECTION</td>
<td>PRIVATE, FIRSTPRIVATE, LASTPRIVATE, REDUCTION</td>
</tr>
<tr>
<td>SINGLE</td>
<td>PRIVATE, FIRSTPRIVATE</td>
</tr>
<tr>
<td>END SINGLE</td>
<td></td>
</tr>
</tbody>
</table>
**Parallel Region Directives**

The `PARALLEL` and `END PARALLEL` directives define a parallel region as follows:

```
!$OMP PARALLEL
  ! parallel region
!$OMP END PARALLEL
```

When a thread encounters a parallel region, it creates a team of threads and becomes the master of the team. You can control the number of threads in a team by the use of an environment variable or a runtime library call, or both.

### Clauses Used

The `PARALLEL` directive takes an optional comma-separated list of clauses that specify as follows:

- **IF**: whether the statements in the parallel region are executed in parallel by a team of threads or serially by a single thread.

<table>
<thead>
<tr>
<th>Clause Type</th>
<th>Valid Clauses</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARALLEL DO</td>
<td>COPYIN, DEFAULT, PRIVATE, FIRSTPRIVATE, LASTPRIVATE, REDUCTION, SHARED, SCHEDULE</td>
</tr>
<tr>
<td>END PARALLEL DO</td>
<td></td>
</tr>
<tr>
<td>PARALLEL SECTIONS</td>
<td>COPYIN, DEFAULT, PRIVATE, FIRSTPRIVATE, LASTPRIVATE, REDUCTION, SHARED</td>
</tr>
<tr>
<td>END PARALLEL SECTIONS</td>
<td></td>
</tr>
<tr>
<td>MASTER END MASTER</td>
<td>None</td>
</tr>
<tr>
<td>CRITICAL[lock] END CRITICAL[lock]</td>
<td>None</td>
</tr>
<tr>
<td>BARRIER</td>
<td>None</td>
</tr>
<tr>
<td>ATOMIC</td>
<td>None</td>
</tr>
<tr>
<td>FLUSH [(list)]</td>
<td>None</td>
</tr>
<tr>
<td>ORDERED END ORDERED</td>
<td>None</td>
</tr>
<tr>
<td>THREADPRIVATE (list)</td>
<td>None</td>
</tr>
</tbody>
</table>
- PRIVATE, FIRSTPRIVATE, SHARED, or REDUCTION: variable types
- DEFAULT: variable data scope attribute
- COPYIN: master thread common block values are copied to THREADPRIVATE copies of the common block

Changing the Number of Threads

Once created, the number of threads in the team remains constant for the duration of that parallel region. To explicitly change the number of threads used in the next parallel region, call the OMP_SET_NUM_THREADS runtime library routine from a serial portion of the program. This routine overrides any value you may have set using the OMP_NUM_THREADS environment variable.

Assuming you have used the OMP_NUM_THREADS environment variable to set the number of threads to 6, you can change the number of threads between parallel regions as follows:

```fortran
CALL OMP_SET_NUM_THREADS (3)
!$OMP PARALLEL
  .
  .
  !$OMP END PARALLEL
CALL OMP_SET_NUM_THREADS (4)
!$OMP PARALLEL DO
  .
  .
  .
!$OMP END PARALLEL DO
```

Setting Units of Work

Use the worksharing directives such as DO, SECTIONS, and SINGLE to divide the statements in the parallel region into units of work and to distribute those units so that each unit is executed by one thread.

In the following example, the !$OMP DO and !$OMP END DO directives and all the statements enclosed by them comprise the static extent of the parallel region:
In the following example, the !$OMP DO and !$OMP END DO directives and all the statements enclosed by them, including all statements contained in the WORK subroutine, comprise the dynamic extent of the parallel region:

```
!$OMP PARALLEL
!$OMP DO
  DO I=1,N
    B(I) = (A(I) + A(I-1))/2.0
  END DO
!$OMP END DO
!$OMP END PARALLEL
```

### Setting Conditional Parallel Region Execution

When an IF clause is present on the PARALLEL directive, the enclosed code region is executed in parallel only if the scalar logical expression evaluates to .TRUE.. Otherwise, the parallel region is serialized. When there is no IF clause, the region is executed in parallel by default.

In the following example, the statements enclosed within the !$OMP DO and !$OMP END DO directives are executed in parallel only if there are more than three processors available. Otherwise the statements are executed serially:

```
!$OMP PARALLEL IF (OMP_GET_NUM_PROCS () .GT. 3)
!$OMP DO
  DO I=1,N
    Y(I) = SQRT(Z(I))
  END DO
!$OMP END DO
!$OMP END PARALLEL
```

If a thread executing a parallel region encounters another parallel region, it creates a new team and becomes the master of that new team. By default, nested parallel regions are always executed by a team of one thread.
To achieve better performance than sequential execution, a parallel region must contain one or more worksharing constructs so that the team of threads can execute work in parallel. It is the contained worksharing constructs that lead to the performance enhancements offered by parallel processing.

Worksharing Construct Directives

A worksharing construct must be enclosed dynamically within a parallel region if the worksharing directive is to execute in parallel. No new threads are launched and there is no implied barrier on entry to a worksharing construct.

The worksharing constructs are:

- **DO and END DO directives**
- **SECTIONS, SECTION, and END SECTIONS directives**
- **SINGLE and END SINGLE directives**

**DO and END DO**

The DO directive specifies that the iterations of the immediately following DO loop must be dispatched across the team of threads so that each iteration is executed by a single thread. The loop that follows a DO directive cannot be a DO WHILE or a DO loop that does not have loop control. The iterations of the DO loop are dispatched among the existing team of threads.

The DO directive optionally lets you:

- Control data scope attributes (see Controlling Data Scope Attributes)
- Use the SCHEDULE clause to specify schedule type and chunk size (see Specifying Schedule Type and Chunk Size)

**Clauses Used**

The clauses for DO directive specify:

- Whether variables are PRIVATE, FIRSTPRIVATE, LASTPRIVATE, or REDUCTION
- How loop iterations are SCHEDULEd onto threads
- In addition, the ORDERED clause must be specified if the ORDERED directive appears
in the dynamic extent of the DO directive.

- If you do not specify the optional NOWAIT clause on the END DO directive, threads synchronize at the END DO directive. If you specify NOWAIT, threads do not synchronize, and threads that finish early proceed directly to the instructions following the END DO directive.

### Usage Rules

- You cannot use a GOTO statement, or any other statement, to transfer control onto or out of the DO construct.

- If you specify the optional END DO directive, it must appear immediately after the end of the DO loop. If you do not specify the END DO directive, an END DO directive is assumed at the end of the DO loop, and threads synchronize at that point.

- The loop iteration variable is private by default, so it is not necessary to declare it explicitly.

### SECTIONS, SECTION and END SECTIONS

Use the noniterative worksharing SECTIONS directive to divide the enclosed sections of code among the team. Each section is executed just one time by one thread.

Each section should be preceded with a SECTION directive, except for the first section, in which the SECTION directive is optional. The SECTION directive must appear within the lexical extent of the SECTIONS and END SECTIONS directives.

The last section ends at the END SECTIONS directive. When a thread completes its section and there are no undispatched sections, it waits at the END SECTION directive unless you specify NOWAIT.

The SECTIONS directive takes an optional comma-separated list of clauses that specifies which variables are PRIVATE, FIRSTPRIVATE, LASTPRIVATE, or REDUCTION.

The following example shows how to use the SECTIONS and SECTION directives to execute subroutines X_AXIS, Y_AXIS, and Z_AXIS in parallel. The first SECTION directive is optional:

```fortran
 !$OMP PARALLEL
 !$OMP SECTIONS
 !$OMP SECTION
   CALL X_AXIS
 !$OMP SECTION
   CALL Y_AXIS
 !$OMP SECTION
   CALL Z_AXIS
 !$OMP END SECTIONS
```
SINGLE and END SINGLE

Use the SINGLE directive when you want just one thread of the team to execute the enclosed block of code.

Threads that are not executing the SINGLE directive wait at the END SINGLE directive unless you specify NOWAIT.

The SINGLE directive takes an optional comma-separated list of clauses that specifies which variables are PRIVATE or FIRSTPRIVATE.

When the END SINGLE directive is encountered, an implicit barrier is erected and threads wait until all threads have finished. This can be overridden by using the NOWAIT option.

In the following example, the first thread that encounters the SINGLE directive executes subroutines OUTPUT and INPUT:

```
!$OMP PARALLEL DEFAULT (SHARED)
   CALL WORK(X)
!$OMP BARRIER
!$OMP SINGLE
   CALL OUTPUT(X)
   CALL INPUT(Y)
!$OMP END SINGLE
   CALL WORK(Y)
!$OMP END PARALLEL
```

Combined Parallel/Worksharing Constructs

The combined parallel/worksharing constructs provide an abbreviated way to specify a parallel region that contains a single worksharing construct. The combined parallel/worksharing constructs are:

- PARALLEL DO
- PARALLEL SECTIONS

PARALLEL DO and END PARALLEL DO

Use the PARALLEL DO directive to specify a parallel region that implicitly contains a
single DO directive.

You can specify one or more of the clauses for the PARALLEL and the DO directives.

The following example shows how to parallelize a simple loop. The loop iteration variable is private by default, so it is not necessary to declare it explicitly. The END PARALLEL DO directive is optional:

```
!$OMP PARALLEL DO
  DO I=1,N
    B(I) = (A(I) + A(I-1)) / 2.0
  END DO
$OMP END PARALLEL DO
```

PARALLEL SECTIONS and END PARALLEL SECTIONS

Use the PARALLEL SECTIONS directive to specify a parallel region that implicitly contains a single SECTIONS directive.

You can specify one or more of the clauses for the PARALLEL and the SECTIONS directives.

The last section ends at the END PARALLEL SECTIONS directive.

In the following example, subroutines X_AXIS, Y_AXIS, and Z_AXIS can be executed concurrently. The first SECTION directive is optional. Note that all SECTION directives must appear in the lexical extent of the PARALLEL SECTIONS/END PARALLEL SECTIONS construct:

```
!$OMP PARALLEL SECTIONS
!$OMP SECTION
  CALL X_AXIS
!$OMP SECTION
  CALL Y_AXIS
!$OMP SECTION
  CALL Z_AXIS
!$OMP END PARALLEL SECTIONS
```

Synchronization Constructs

Synchronization constructs are used to ensure the consistency of shared data and to coordinate parallel execution among threads.

The synchronization constructs are:
The ATOMIC directive

Use the ATOMIC directive to ensure that a specific memory location is updated atomically instead of exposing the location to the possibility of multiple, simultaneously writing threads.

This directive applies only to the immediately following statement, which must have one of the following forms:

\[ x = x \text{ operator } expr \]
\[ x = expr \text{ operator } x \]
\[ x = \text{ intrinsic } (x, expr) \]
\[ x = \text{ intrinsic } (expr, x) \]

In the preceding statements:

- \( x \) is a scalar variable of intrinsic type
- \( expr \) is a scalar expression that does not reference \( x \)
- \( \text{intrinsic} \) is either MAX, MIN, IAND, IOR, or IEBR
- \( \text{operator} \) is either +, *, -, /, .AND., .OR., .EQV., or .NEQV.

This directive permits optimization beyond that of a critical section around the assignment. An implementation can replace all ATOMIC directives by enclosing the statement in a critical section. All of these critical sections must use the same unique name.

Only the load and store of \( x \) are atomic; the evaluation of \( expr \) is not atomic. To avoid race conditions, all updates of the location in parallel must be protected by using the ATOMIC directive, except those that are known to be free of race conditions. The function \( \text{intrinsic} \), the operator \( \text{operator} \), and the assignment must be the intrinsic function, operator, and assignment.
This restriction applies to the ATOMIC directive: All references to storage location \( x \) must have the same type parameters.

In the following example, the collection of \( Y \) locations is updated atomically:

```fortran
!$OMP ATOMIC
Y = Y + B(I)
```

**BARRIER Directive**

To synchronize all threads within a parallel region, use the BARRIER directive. You can use this directive only within a parallel region defined by using the PARALLEL directive. You cannot use the BARRIER directive within the DO, PARALLEL DO, SECTIONS, PARALLEL SECTIONS, and SINGLE directives.

When encountered, each thread waits at the BARRIER directive until all threads have reached the directive.

In the following example, the BARRIER directive ensures that all threads have executed the first loop and that it is safe to execute the second loop:

```fortran
!$OMP PARALLEL
!$OMP DO PRIVATE(i)
   DO i = 1, 100
      b(i) = i
   END DO
!$OMP BARRIER
!$OMP DO PRIVATE(i)
   DO i = 1, 100
      a(i) = b(101-i)
   END DO
!$OMP END PARALLEL
```

**CRITICAL and END CRITICAL**

Use the CRITICAL and END CRITICAL directives to restrict access to a block of code, referred to as a critical section, to one thread at a time.

A thread waits at the beginning of a critical section until no other thread in the team is executing a critical section having the same name.

When a thread enters the critical section, a latch variable is set to closed and all other threads are locked out. When the thread exits the critical section at the END CRITICAL directive, the latch variable is set to open, allowing another thread access to the critical section.
If you specify a critical section name in the `CRITICAL` directive, you must specify the same name in the `END CRITICAL` directive. If you do not specify a name for the `CRITICAL` directive, you cannot specify a name for the `END CRITICAL` directive.

All unnamed `CRITICAL` directives map to the same name. Critical section names are global to the program.

The following example includes several `CRITICAL` directives, and illustrates a queuing model in which a task is dequeued and worked on. To guard against multiple threads dequeuing the same task, the dequeuing operation must be in a critical section. Because there are two independent queues in this example, each queue is protected by `CRITICAL` directives having different names, `X_AXIS` and `Y_AXIS`, respectively:

```fortran
!$OMP PARALLEL DEFAULT(PRIVATE,SHARED (X,Y)
!$OMP CRITICAL(X_AXIS)
   CALL DEQUEUE(IX_NEXT, X)
!$OMP END CRITICAL(X_AXIS)
   CALL WORK(IX_NEXT, X)
!$OMP CRITICAL(Y_AXIS)
   CALL DEQUEUE(IY_NEXT,Y)
!$OMP END CRITICAL(Y_AXIS)
   CALL WORK(IY_NEXT, Y)
!$OMP END PARALLEL
```

Unnamed critical sections use the global lock from the Pthread package. This allows you to synchronize with other code by using the same lock. Named locks are created and maintained by the compiler and can be significantly more efficient.

**FLUSH Directive**

Use the `FLUSH` directive to identify a synchronization point at which a consistent view of memory is provided. Thread-visible variables are written back to memory at this point.

To avoid flushing all thread-visible variables at this point, include a list of comma-separated named variables to be flushed.

The following example uses the `FLUSH` directive for point-to-point synchronization between thread 0 and thread 1 for the variable `ISYNC`:

```fortran
!$OMP PARALLEL DEFAULT(PRIVATE),SHARED(ISYNC)
   IAM = OMP_GET_THREAD_NUM()
   ISYNC(IAM) = 0
!$OMP BARRIER
   CALL WORK()
   ! I Am Done With My Work, Synchronize With My Neighbor
```
MASTER and END MASTER

Use the MASTER and END MASTER directives to identify a block of code that is executed only by the master thread.

The other threads of the team skip the code and continue execution. There is no implied barrier at the END MASTER directive.

In the following example, only the master thread executes the routines OUTPUT and INPUT:

```fortran
ISYNC(IAM) = 1
!$OMP FLUSH(ISYNC)
! Wait Till Neighbor Is Done
   DO WHILE (ISYNC(NEIGH) .EQ. 0)
    !$OMP FLUSH(ISYNC)
    END DO
!$OMP END PARALLEL

ORDERED and END ORDERED

Use the ORDERED and END ORDERED directives within a DO construct to allow work within an ordered section to execute sequentially while allowing work outside the section to execute in parallel.

When you use the ORDERED directive, you must also specify the ORDERED clause on the DO directive.

Only one thread at a time is allowed to enter the ordered section, and then only in the order of loop iterations.

In the following example, the code prints out the indexes in sequential order:
THREADPRIVATE Directive

You can make named common blocks private to a thread, but global within the thread, by using the THREADPRIVATE directive.

Each thread gets its own copy of the common block with the result that data written to the common block by one thread is not directly visible to other threads. During serial portions and MASTER sections of the program, accesses are to the master thread copy of the common block.

You cannot use a thread private common block or its constituent variables in any clause other than the COPYIN clause.

In the following example, common blocks BLK1 and FIELDS are specified as thread private:

```fortran
COMMON /BLK1/ SCRATCH
    COMMON /FIELDS/ XFIELD, YFIELD,
    ZFIELD
!$OMP THREADPRIVATE(/BLK1/,/FIELDS/)
```

Data Scope Attribute Clauses Overview

You can use several directive clauses to control the data scope attributes of variables for the duration of the construct in which you specify them. If you do not specify a data scope attribute clause on a directive, the default is SHARED for those variables affected by the directive.

Each of the data scope attribute clauses accepts a list, which is a comma-separated list of named variables or named common blocks that are accessible in the scoping unit. When you specify named common blocks, they must appear between slashes (/name/).

Not all of the clauses are allowed on all directives, but the directives to which each clause applies are listed in the clause descriptions.

The data scope attribute clauses are:
COPYIN Clause

Use the COPYIN clause on the PARALLEL, PARALLEL DO, and PARALLEL SECTIONS directives to copy the data in the master thread common block to the thread private copies of the common block. The copy occurs at the beginning of the parallel region. The COPYIN clause applies only to common blocks that have been declared THREADPRIVATE.

You do not have to specify a whole common block to be copied in; you can specify named variables that appear in the THREADPRIVATE common block. In the following example, the common blocks BLK1 and FIELDS are specified as thread private, but only one of the variables in common block FIELDS is specified to be copied in:

```
COMMON /BLK1/ SCRATCH
COMMON /FIELDS/ XFIELD, YFIELD, ZFIELD
!$OMP THREADPRIVATE(/BLK1/, /FIELDS/)
!$OMP PARALLEL DEFAULT(PRIVATE),COPYIN (/BLK1/,ZFIELD)
```

DEFAULT Clause

Use the DEFAULT clause on the PARALLEL, PARALLEL DO, and PARALLEL SECTIONS directives to specify a default data scope attribute for all variables within the lexical extent of a parallel region. Variables in THREADPRIVATE common blocks are not affected by this clause. You can specify only one DEFAULT clause on a directive. The default data scope attribute can be one of the following:

- PRIVATE

  Makes all named objects in the lexical extent of the parallel region private to a thread. The objects include common block variables, but exclude THREADPRIVATE
variables.

- **SHARED**

  Makes all named objects in the lexical extent of the parallel region shared among all the threads in the team.

- **NONE**

  Declares that there is no implicit default as to whether variables are PRIVATE or SHARED. You must explicitly specify the scope attribute for each variable in the lexical extent of the parallel region.

If you do not specify the **DEFAULT** clause, the default is **DEFAULT (SHARED)**. However, loop control variables are always **PRIVATE** by default.

You can exempt variables from the default data scope attribute by using other scope attribute clauses on the parallel region as shown in the following example:

```
!$OMP PARALLEL DO DEFAULT(PRIVATE), FIRSTPRIVATE (I), SHARED (X),
  !$OMP& SHARED (R) LASTPRIVATE (I)
```

### PRIVATE, FIRSTPRIVATE, and LASTPRIVATE Clauses

**PRIVATE**

Use the **PRIVATE** clause on the **PARALLEL**, **DO**, **SECTIONS**, **SINGLE**, **PARALLEL DO**, and **PARALLEL SECTIONS** directives to declare variables to be private to each thread in the team.

The behavior of variables declared **PRIVATE** is as follows:

- A new object of the same type and size is declared once for each thread in the team, and the new object is no longer storage associated with the original object.

- All references to the original object in the lexical extent of the directive construct are replaced with references to the private object.

- Variables defined as **PRIVATE** are undefined for each thread on entering the construct, and the corresponding shared variable is undefined on exit from a parallel construct.

- Contents, allocation state, and association status of variables defined as **PRIVATE** are undefined when they are referenced outside the lexical extent, but inside the
dynamic extent, of the construct unless they are passed as actual arguments to called routines.

In the following example, the values of I and J are undefined on exit from the parallel region:

```fortran
INTEGER I, J
  I = 1
  J = 2
!$OMP PARALLEL PRIVATE(I) FIRSTPRIVATE(J)
  I = 3
  J = J + 2
!$OMP END PARALLEL
  PRINT *, I, J
```

**FIRSTPRIVATE**

Use the `FIRSTPRIVATE` clause on the `PARALLEL`, `DO`, `SECTIONS`, `SINGLE`, `PARALLEL DO`, and `PARALLEL SECTIONS` directives to provide a superset of the `PRIVATE` clause functionality.

In addition to the `PRIVATE` clause functionality, private copies of the variables are initialized from the original object existing before the parallel construct.

**LASTPRIVATE**

Use the `LASTPRIVATE` clause on the `DO`, `SECTIONS`, `PARALLEL DO`, and `PARALLEL SECTIONS` directives to provide a superset of the `PRIVATE` clause functionality.

When the `LASTPRIVATE` clause appears on a `DO` or `PARALLEL DO` directive, the thread that executes the sequentially last iteration updates the version of the object it had before the construct.

When the `LASTPRIVATE` clause appears on a `SECTIONS` or `PARALLEL SECTIONS` directive, the thread that executes the lexically last section updates the version of the object it had before the construct.

Subobjects that are not assigned a value by the last iteration of the `DO` loop or the lexically last `SECTION` directive are undefined after the construct.

Correct execution sometimes depends on the value that the last iteration of a loop assigns to a variable. You must list all such variables as arguments to a `LASTPRIVATE` clause so that the values of the variables are the same as when the loop is executed sequentially. As shown in the following example, the value of I at the end of the parallel region is equal to N+1, as it would be with sequential execution.
Use the `REDUCTION` clause on the `PARALLEL`, `DO`, `SECTIONS`, `PARALLEL DO`, and `PARALLEL SECTIONS` directives to perform a reduction on the specified variables by using an operator or intrinsic as shown:

```fortran
!$OMP PARALLEL
!$OMP DO LASTPRIVATE(I)
    DO I=1,N
        A(I) = B(I) + C(I)
    END DO
!$OMP END PARALLEL
CALL REVERSE(I)
```

**REDUCTION Clause**

**Operator** can be one of the following: `+`, `*`, `−`, `.AND.`, `.OR.`, `.EQV.`, or `.NEQV.`

**Intrinsic** can be one of the following: `MAX`, `MIN`, `IAND`, `IOR`, or `IEOR`.

The specified variables must be named scalar variables of intrinsic type and must be `SHARED` in the enclosing context. A private copy of each specified variable is created for each thread as if you had used the `PRIVATE` clause. The private copy is initialized to a value that depends on the operator or intrinsic as shown in the Table `Operators/Intrinsics and Initialization Values for Reduction Variables`. The actual initialization value is consistent with the data type of the reduction variable.

**Operators/Intrinsics and Initialization Values for Reduction Variables**

<table>
<thead>
<tr>
<th>Operator/Intrinsic</th>
<th>Initialization Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>*</td>
<td>1</td>
</tr>
<tr>
<td>−</td>
<td>0</td>
</tr>
<tr>
<td>.AND.</td>
<td>.TRUE.</td>
</tr>
<tr>
<td>.OR.</td>
<td>.FALSE.</td>
</tr>
<tr>
<td>.EQV.</td>
<td>.TRUE.</td>
</tr>
<tr>
<td>.NEQV.</td>
<td>.FALSE.</td>
</tr>
<tr>
<td>MAX</td>
<td>Largest representable number</td>
</tr>
<tr>
<td>MIN</td>
<td>Smallest representable number</td>
</tr>
</tbody>
</table>
At the end of the construct to which the reduction applies, the shared variable is updated to reflect the result of combining the original value of the SHARED reduction variable with the final value of each of the private copies using the specified operator.

Except for subtraction, all of the reduction operators are associative and the compiler can freely reassociate the computation of the final value. The partial results of a subtraction reduction are added to form the final value.

The value of the shared variable becomes undefined when the first thread reaches the clause containing the reduction, and it remains undefined until the reduction computation is complete. Normally, the computation is complete at the end of the REDUCTION construct. However, if you use the REDUCTION clause on a construct to which NOWAIT is also applied, the shared variable remains undefined until a barrier synchronization has been performed. This ensures that all of the threads have completed the REDUCTION clause.

The REDUCTION clause is intended to be used on a region or worksharing construct in which the reduction variable is used only in reduction statements having one of the following forms:

\[
x = x \text{ operator } expr \\
x = \text{expr operator } x \text{ (except for subtraction)} \\
x = \text{intrinsic } (x, \text{expr}) \\
x = \text{intrinsic } (\text{expr}, x)
\]

Some reductions can be expressed in other forms. For instance, a MAX reduction might be expressed as follows:

\[
\text{IF } (x .LT. \text{expr}) x = \text{expr}
\]

Alternatively, the reduction might be hidden inside a subroutine call. Be careful that the operator specified in the REDUCTION clause matches the reduction operation.

Any number of reduction clauses can be specified on the directive, but a variable can appear only once in a REDUCTION clause for that directive as shown in the following example:

\[
!$OMP \text{ DO REDUCTION(+: } A, Y), \text{REDUCTION(.OR.: } AM)\]

The following example shows how to use the REDUCTION clause:

<table>
<thead>
<tr>
<th>IAND,</th>
<th>All bits on</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOR</td>
<td>0</td>
</tr>
<tr>
<td>IEOR</td>
<td>0</td>
</tr>
</tbody>
</table>
SHARED Clause

Use the `SHARED` clause on the `PARALLEL`, `PARALLEL DO`, and `PARALLEL SECTIONS` directives to make variables shared among all the threads in a team.

In the following example, the variables `X` and `NPOINTS` are shared among all the threads in the team:

```fortran
!$OMP PARALLEL DEFAULT(PRIVATE),SHARED (A,B),REDUCTION(+: A,B)  
DO I=1,N  
   CALL WORK(ALLOCAL,BLOCAL)  
   A = A + ALOCAL  
   B = B + BLOCAL  
END DO  
!$OMP END PARALLEL DO
```

Specifying Schedule Type and Chunk Size

The `SCHEDULE` clause of the `DO` or `PARALLEL DO` directive specifies a scheduling algorithm that determines how iterations of the `DO` loop are divided among and dispatched to the threads of the team. The `SCHEDULE` clause applies only to the current `DO` or `PARALLEL DO` directive.

Within the `SCHEDULE` clause, you must specify a `schedule type` and, optionally, a `chunk size`. A `chunk` is a contiguous group of iterations dispatched to a thread. Chunk size must be a scalar integer expression.

The following list describes the schedule types and how the chunk size affects scheduling:

- **STATIC**

  The iterations are divided into pieces having a size specified by chunk. The pieces are statically dispatched to threads in the team in a round-robin manner in the order of thread number.

  When chunk is not specified, the iterations are first divided into contiguous pieces by dividing the number of iterations by the number of threads in the team. Each piece is
then dispatched to a thread before loop execution begins.

- **DYNAMIC**

  The iterations are divided into pieces having a size specified by chunk. As each thread finishes its currently dispatched piece of the iteration space, the next piece is dynamically dispatched to the thread.

  When no chunk is specified, the default is 1.

- **GUIDED**

  The chunk size is decreased exponentially with each succeeding dispatch. Chunk specifies the minimum number of iterations to dispatch each time. If there are less than chunk number of iterations remaining, the rest are dispatched.

  When no chunk is specified, the default is 1.

- **RUNTIME**

  The decision regarding scheduling is deferred until run time. The schedule type and chunk size can be chosen at run time by using the `OMP_SCHEDULE` environment variable.

  When you specify RUNTIME, you cannot specify a chunk size.

The following list shows which schedule type is used, in priority order:

1. The schedule type specified in the `SCHEDULE` clause of the current `DO` or `PARALLEL DO` directive

2. If the schedule type for the current `DO` or `PARALLEL DO` directive is RUNTIME, the default value specified in the `OMP_SCHEDULE` environment variable

3. The compiler default schedule type of STATIC

The following list shows which chunk size is used, in priority order:

1. The chunk size specified in the `SCHEDULE` clause of the current `DO` or `PARALLEL DO` directive

2. For RUNTIME schedule type, the value specified in the `OMP_SCHEDULE` environment variable

3. For DYNAMIC and GUIDED schedule types, the default value 1

4. If the schedule type for the current `DO` or `PARALLEL DO` directive is STATIC, the loop iteration space divided by the number of threads in the team.
OpenMP Support Libraries

The Intel Fortran Compiler with OpenMP support provides a production support library, libguide.lib. This library enables you to run an application under different execution modes. It is used for normal or performance-critical runs on applications that have already been tuned.

Execution modes

The compiler with OpenMP enables you to run an application under different execution modes that can be specified at run time. The libraries support the serial, turnaround, and throughput modes. These modes are selected by using the kmp_library environment variable at run time.

Serial

The serial mode forces parallel applications to run on a single processor.

Turnaround

In a dedicated (batch or single user) parallel environment where all processors are exclusively allocated to the program for its entire run, it is most important to effectively utilize all of the processors all of the time. The turnaround mode is designed to keep active all of the processors involved in the parallel computation in order to minimize the execution time of a single job. In this mode, the worker threads actively wait for more parallel work, without yielding to other threads.

Note

Avoid over-allocating system resources. This occurs if either too many threads have been specified, or if too few processors are available at run time. If system resources are over-allocated, this mode will cause poor performance. The throughput mode should be used instead if this occurs.

Throughput

In a multi-user environment where the load on the parallel machine is not constant or where the job stream is not predictable, it may be better to design and tune for throughput. This minimizes the total time to run multiple jobs simultaneously. In this mode, the worker threads will yield to other threads while waiting for more parallel work.

The throughput mode is designed to make the program aware of its environment (that is, the system load) and to adjust its resource usage to produce efficient execution in a dynamic environment. This mode is the default.
OpenMP Environment Variables

This topic describes the standard OpenMP environment variables (with the OMP_ prefix) and Intel-specific environment variables (with the KMP_ prefix) that are Intel extensions to the standard Fortran Compiler.

**Standard Environment Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMP_SCHEDULE</td>
<td>Sets the run-time schedule type and chunk size.</td>
<td>static, no chunk size specified</td>
</tr>
<tr>
<td>OMP_NUM_THREADS</td>
<td>Sets the number of threads to use during execution.</td>
<td>Number of processors</td>
</tr>
<tr>
<td>OMP_DYNAMIC</td>
<td>Enables (true) or disables (false) the dynamic adjustment of the number of threads.</td>
<td>false</td>
</tr>
<tr>
<td>OMP_NESTED</td>
<td>Enables (true) or disables (false) nested parallelism.</td>
<td>false</td>
</tr>
</tbody>
</table>

**Intel Extension Environment Variables**

<table>
<thead>
<tr>
<th>Environment Variable</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>KMP_LIBRARY</td>
<td>Selects the OpenMP runtime library throughput. The options for the variable value are: serial, turnaround, or throughput indicating the execution mode. The default value of throughput is used if this variable is not specified.</td>
<td>throughput (execution mode)</td>
</tr>
</tbody>
</table>
| KMP_STACKSIZE        | Sets the number of bytes to allocate for each parallel thread to use as its private stack. Use the optional suffix b, k, m, g, or t, to specify bytes, kilobytes, megabytes, gigabytes, or terabytes. | IA-32: 2m
Itanium compiler: 4m |
OpenMP Runtime Library Routines

OpenMP provides several runtime library routines to assist you in managing your program in parallel mode. Many of these runtime library routines have corresponding environment variables that can be set as defaults. The runtime library routines enable you to dynamically change these factors to assist in controlling your program. In all cases, a call to a runtime library routine overrides any corresponding environment variable.

The following table specifies the interface to these routines. The names for the routines are in user name space. The `omp_lib.f`, `omp_lib.h` and `omp_lib.mod` header files are provided in the include directory of your compiler installation. The `omp_lib.h` header file is provided in the include directory of your compiler installation for use with the Fortran INCLUDE statement. The `omp_lib.mod` file is provided in the Include directory for use with the Fortran USE statement.

There are definitions for two different locks, `omp_lock_t` and `omp_nest_lock_t`, which are used by the functions in the table that follows.

This topic provides a summary of the OpenMP runtime library routines. For detailed descriptions, see the [OpenMP Fortran version 2.0 specifications](#).

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Execution Environment Routines</strong></td>
<td></td>
</tr>
<tr>
<td>subroutine omp_set_num_threads (num_threads) integer num_threads</td>
<td>Sets the number of threads to use for subsequent parallel regions.</td>
</tr>
<tr>
<td>integer function omp_get_num_threads()</td>
<td>Returns the number of threads that are being used in the current parallel region.</td>
</tr>
<tr>
<td>integer function omp_get_max_threads()</td>
<td>Returns the maximum number of threads that are available for parallel execution.</td>
</tr>
<tr>
<td>integer function omp_get_thread_num()</td>
<td>Determines the unique thread number of the thread currently executing this section of code.</td>
</tr>
<tr>
<td>integer function omp_get_num_procs()</td>
<td>Determines the number of processors available to the program.</td>
</tr>
<tr>
<td>logical function omp_in_parallel()</td>
<td>Returns .true. if called within the dynamic extent of a parallel region executing in parallel; otherwise returns .false..</td>
</tr>
<tr>
<td>Function/Routine</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>subroutine omp_set_dynamic</td>
<td>Enables or disables dynamic adjustment of the number of threads used to execute a parallel region. If <code>dynamic_threads</code> is <code>.true.</code>, dynamic threads are enabled. If <code>dynamic_threads</code> is <code>.false.</code>, dynamic threads are disabled. Dynamics threads are disabled by default.</td>
</tr>
<tr>
<td>logical function omp_get_dynamic</td>
<td>Returns <code>.true.</code> if dynamic thread adjustment is enabled, otherwise returns <code>.false.</code>.</td>
</tr>
<tr>
<td>subroutine omp_set_nested</td>
<td>Enables or disables nested parallelism. If <code>nested</code> is <code>.true.</code>, nested parallelism is enabled. If <code>nested</code> is <code>.false.</code>, nested parallelism is disabled. Nested parallelism is disabled by default.</td>
</tr>
<tr>
<td>logical function omp_get_nested</td>
<td>Returns <code>.true.</code> if nested parallelism is enabled, otherwise returns <code>.false.</code>.</td>
</tr>
</tbody>
</table>

**Lock Routines**

<table>
<thead>
<tr>
<th>Function/Routine</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>subroutine omp_init_lock</td>
<td>Initializes the lock associated with <code>lock</code> for use in subsequent calls.</td>
</tr>
<tr>
<td>subroutine omp_destroy_lock</td>
<td>Causes the lock associated with <code>lock</code> to become undefined.</td>
</tr>
<tr>
<td>subroutine omp_set_lock</td>
<td>Forces the executing thread to wait until the lock associated with <code>lock</code> is available. The thread is granted ownership of the lock when it becomes available.</td>
</tr>
<tr>
<td>subroutine omp_unset_lock</td>
<td>Releases the executing thread from ownership of the lock associated with <code>lock</code>. The behavior is undefined if the executing thread does not own the lock associated with <code>lock</code>.</td>
</tr>
<tr>
<td>logical omp_test_lock</td>
<td>Attempts to set the lock associated with <code>lock</code>. If successful, returns <code>.true.</code>, otherwise returns <code>.false.</code>.</td>
</tr>
</tbody>
</table>
### Intel Extension Routines

The Intel® Fortran Compiler implements the following group of routines as an extension to the OpenMP runtime library: getting and setting stack size for parallel threads and memory allocation.

The Intel extension routines described in this section can be used for low-level debugging to verify that the library code and application are functioning as intended. It is recommended to use these routines with caution because using them requires the use of the `-openmp_stubs` command-line option to execute the program sequentially. These routines are also generally not recognized by other vendor’s OpenMP-compliant compilers.

<table>
<thead>
<tr>
<th>Routine</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>omp_init_nest_lock</code></td>
<td>Initializes the nested lock associated with <code>lock</code> for use in the subsequent calls.</td>
</tr>
<tr>
<td><code>omp_destroy_nest_lock</code></td>
<td>Causes the nested lock associated with <code>lock</code> to become undefined.</td>
</tr>
<tr>
<td><code>omp_set_nest_lock</code></td>
<td>Forces the executing thread to wait until the nested lock associated with <code>lock</code> is available. The thread is granted ownership of the nested lock when it becomes available.</td>
</tr>
<tr>
<td><code>omp_unset_nest_lock</code></td>
<td>Releases the executing thread from ownership of the nested lock associated with <code>lock</code> if the nesting count is zero. Behavior is undefined if the executing thread does not own the nested lock associated with <code>lock</code>.</td>
</tr>
<tr>
<td><code>omp_test_nest_lock</code></td>
<td>Attempts to set the nested lock associated with <code>lock</code>. If successful, returns the nesting count, otherwise returns zero.</td>
</tr>
<tr>
<td><strong>Timing Routines</strong></td>
<td></td>
</tr>
<tr>
<td><code>omp_get_wtime()</code></td>
<td>Returns a double-precision value equal to the elapsed wallclock time (in seconds) relative to an arbitrary reference time. The reference time does not change during program execution.</td>
</tr>
<tr>
<td><code>omp_get_wtick()</code></td>
<td>Returns a double-precision value equal to the number of seconds between successive clock ticks.</td>
</tr>
</tbody>
</table>
which may cause the link stage to fail for these other compilers.

**Stack Size**

In most cases, directives can be used in place of the extension library routines. For example, the stack size of the parallel threads may be set using the `KMP_STACKSIZE` environment variable rather than the `kmp_set_stacksize()` library routine.

![Note]

A runtime call to an Intel extension routine takes precedence over the corresponding environment variable setting.

See the definitions of stack size routines in the table that follows.

**Memory Allocation**

The Intel® Fortran Compiler implements a group of memory allocation routines as an extension to the OpenMP* runtime library to enable threads to allocate memory from a heap local to each thread. These routines are: `kmp_malloc`, `kmp_calloc`, and `kmp_realloc`.

The memory allocated by these routines must also be freed by the `kmp_free` routine. While it is legal for the memory to be allocated by one thread and `kmp_free`d by a different thread, this mode of operation has a slight performance penalty.

See the definitions of these routines in the table that follows.

<table>
<thead>
<tr>
<th>Function/Routine</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stack Size</strong></td>
<td></td>
</tr>
<tr>
<td>function</td>
<td>Returns the number of bytes that will be allocated for each parallel thread to use as its private stack. This value can be changed via the <code>kmp_get_stacksize_s</code> routine, prior to the first parallel region or via the KMP_STACKSIZE environment variable.</td>
</tr>
<tr>
<td><code>kmp_get_stacksize_s()</code></td>
<td>integer (kind=kmp_size_t_kind)</td>
</tr>
<tr>
<td><code>kmp_get_stacksize_s</code></td>
<td></td>
</tr>
<tr>
<td>function</td>
<td>This routine is provided for backwards compatibility only; use <code>kmp_get_stacksize_s</code> routine for compatibility across different families of Intel processors.</td>
</tr>
<tr>
<td><code>kmp_get_stacksize</code></td>
<td>integer <code>kmp_get_stacksize</code></td>
</tr>
<tr>
<td>subroutine</td>
<td>Sets to size the number of bytes that will be allocated for each parallel thread to use as its private stack. This value can also be set via the KMP_STACKSIZE environment variable. In order for <code>kmp_set_stacksize_s</code> to have an effect, it must be called before the beginning of the first (dynamically executed) parallel region in the</td>
</tr>
<tr>
<td><code>kmp_set_stacksize_s(size)</code></td>
<td>integer (kind=kmp_size_t_kind) <code>size</code></td>
</tr>
</tbody>
</table>
Examples of OpenMP Usage

The following examples show how to use the OpenMP feature. See more examples in the OpenMP Fortran version 2.0 specifications.

**do: A Simple Difference Operator**

This example shows a simple parallel loop where each iteration contains a different number of instructions. To get good load balancing, dynamic scheduling is used. The end do has a nowait because there is an implicit barrier at the end of the parallel region.
do: Two Difference Operators

This example shows two parallel regions fused to reduce fork/join overhead. The first end do has a nowait because all the data used in the second loop is different than all the data used in the first loop.
**sections: Two Difference Operators**

This example demonstrates the use of the `sections` directive. The logic is identical to the preceding `do` example, but uses `sections` instead of `do`. Here the speedup is limited to 2 because there are only two units of work whereas in `do: Two Difference Operators` above there are \( n-1 + m-1 \) units of work.

```fortran
subroutine sections_1
  (a,b,c,d,m,n)
real a(n,n), b(n,n), c(m,m), d(m,m)
!$omp parallel
!$omp& shared(a,b,c,d,m,n)
!$omp& private(i,j)
!$omp sections
!$omp section
d oi=2 ,n
do i = 2, n
do j = 1, i
  b(j,i)=( a(j,i) + a(j,i-1) ) / 2
endo
endo

!$omp section
do i = 2, m
do j = 1, i
d(j,i)=( c(j,i) + c(j,i-1) ) / 2
endo
endo
!$omp end sections nowait
!$omp end parallel
end
```

**single: Updating a Shared Scalar**

This example demonstrates how to use a `single` construct to update an element of the shared array `a`. The optional `nowait` after the first loop is omitted because it is necessary to wait at the end of the loop before proceeding into the `single` construct.
Auto-parallelization

The auto-parallelization feature of the Intel® Fortran Compiler automatically translates serial portions of the input program into equivalent multithreaded code. The auto-parallelizer analyzes the dataflow of the program’s loops and generates multithreaded code for those loops which can be safely and efficiently executed in parallel. This enables the potential exploitation of the parallel architecture found in symmetric multiprocessor (SMP) systems.

Automatic parallelization relieves the user from:

- having to deal with the details of finding loops that are good worksharing candidates
- performing the dataflow analysis to verify correct parallel execution
- partitioning the data for threaded code generation as is needed in programming with OpenMP* directives.

The parallel runtime support provides the same runtime features as found in OpenMP, such as handling the details of loop iteration modification, thread scheduling, and synchronization.

While OpenMP directives enable serial applications to transform into parallel applications quickly, the programmer must explicitly identify specific portions of the application code that contain parallelism and add the appropriate compiler directives. Auto-parallelization triggered by the -parallel option automatically identifies those loop structures, which

```fortran
subroutine sp_1a
  (a,b,n)
real a(n), b(n)
!$omp parallel
!$omp& shared(a,b,n)
!$omp& private(i)
!$omp do
doi=1 ,n
  a(i) = 1.0 / a(i)
enddo
!$omp single
  a(1) = min( a(1), 1.0 )
!$omp end single
!$omp do
doi=1 ,n
  b(i) = b(i) / a(i)
enddo
!$omp end do nowait
!$omp end parallel
end
```
contain parallelism. During compilation, the compiler automatically attempts to decompose the code sequences into separate threads for parallel processing. No other effort by the programmer is needed.

The following example illustrates how a loop’s iteration space can be divided so that it can be executed concurrently on two threads:

**Original Serial Code**

```fortran
do i=1,100
   a(i) = a(i) + b(i) * c(i)
enddo
```

**Transformed Parallel Code**

<table>
<thead>
<tr>
<th>Thread 1</th>
<th>Thread 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>do i=1,50</code></td>
<td><code>do i=50,100</code></td>
</tr>
<tr>
<td><code>a(i) = a(i) + b(i) * c(i)</code></td>
<td><code>a(i) = a(i) + b(i) * c(i)</code></td>
</tr>
<tr>
<td><code>enddo</code></td>
<td><code>enddo</code></td>
</tr>
</tbody>
</table>

**Programming with Auto-parallelization**

Auto-parallelization feature implements some concepts of OpenMP, such as worksharing construct (with the PARALLEL DO directive). See Programming with OpenMP for worksharing construct. This section provides specifics of auto-parallelization.

**Guidelines for Effective Auto-parallelization Usage**

A loop is parallelizable if:

- The loop is countable at compile time: this means that an expression representing how many times the loop will execute (also called "the loop trip count") can be generated just before entering the loop.

- There are no FLOW (READ after WRITE), OUTPUT (WRITE after READ) or ANTI (WRITE after READ) loop-carried data dependences. A loop-carried data dependence occurs when the same memory location is referenced in different iterations of the loop. At the compiler’s discretion, a loop may be parallelized if any assumed inhibiting loop-carried dependencies can be resolved by runtime dependency testing.

The compiler may generate a runtime test for the profitability of executing in parallel for loop
with loop parameters that are not compile-time constants.

**Coding Guidelines**

Enhance the power and effectiveness of the auto-parallelizer by following these coding guidelines:

- Expose the trip count of loops whenever possible; specifically use constants where the trip count is known and save loop parameters in local variables.

- Avoid placing structures inside loop bodies that the compiler may assume to carry dependent data, for example, procedure calls, ambiguous indirect references or global references.

- Insert the `!DIR$ PARALLEL` directive to disambiguate assumed data dependencies.

- Insert the `!DIR$ NOPARALLEL` directive before loops known to have insufficient work to justify the overhead of sharing among threads.

**Auto-parallelization Data Flow**

For auto-parallelization processing, the compiler performs the following steps:

**Data flow analysis --- Loop classification --- Dependence analysis --- High-level parallelization --- Data partitioning --- Multi-threaded code generation.**

These steps include:

- Data flow analysis: compute the flow of data through the program

- Loop classification: determine loop candidates for parallelization based on correctness and efficiency as shown by threshold analysis

- Dependence analysis: compute the dependence analysis for references in each loop nest

- High-level parallelization:
  - analyze dependence graph to determine loops which can execute in parallel.
  - compute runtime dependency

- Data partitioning: examine data reference and partition based on the following types of access: **SHARED, PRIVATE, and FIRSTPRIVATE**

- Multi-threaded code generation:
- modify loop parameters
- generate entry/exit per threaded task
- generate calls to parallel runtime routines for thread creation and synchronization

Auto-parallelization: Enabling, Options, Directives, and Environment Variables

To enable the auto-parallelizer, use the -parallel option. The -parallel option detects parallel loops capable of being executed safely in parallel and automatically generates multithreaded code for these loops. An example of the command using auto-parallelization is as follows:

**IA-32 compilations:**

```
prompt> ifc -c -parallel myprog.f
```

**Itanium®-based compilations:**

```
prompt> efc -c -parallel myprog.f
```

### Auto-parallelization Options

The -parallel option enables the auto-parallelizer if the -O2 (or -O3) optimization option is also on (the default is -O2). The -parallel option detects parallel loops capable of being executed safely in parallel and automatically generates multithreaded code for these loops.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-parallel</td>
<td>Enables the auto-parallelizer</td>
</tr>
<tr>
<td>-par_threshold{1-100}</td>
<td>Controls the work threshold needed for auto-parallelization, see later subsection.</td>
</tr>
<tr>
<td>-par_report{1</td>
<td>2</td>
</tr>
</tbody>
</table>

### Auto-parallelization Directives

Auto-parallelization uses two specific directives, !DIR$ PARALLEL and !DIR$ NOPARALLEL.

**Auto-parallelization Directives Format and Syntax**
The format of Intel Fortran auto-parallelization compiler directive is:

```
<prefix> <directive>
```

where the brackets above mean:

- `<xxx>`: the prefix and directive are required

**For fixed form** source input, the prefix is `!DIR$` or `CDIR$`

**For free form** source input, the prefix is `!DIR$` only.

The prefix is followed by the directive name; for example:

```
!DIR$ PARALLEL
```

Since auto-parallelization directives begin with an exclamation point, the directives take the form of comments if you omit the `-parallel` option.

**Examples**

The `!DIR$ PARALLEL` directive instructs the compiler to ignore dependencies which it assumes may exist and which would prevent correct parallelization in the immediately following loop. However, if dependencies are proven, they are not ignored.

The `!DIR$ NOPARALLEL` directive disables auto-parallelization for the immediately following loop.

```fortran
program main
parameter (n=100)
integer x(n), a(n)

!DIR$ NOPARALLEL
do i=1,n
  x(i) = i
enddo

!DIR$ PARALLEL
do i=1,n
  a( x(i) ) = i
enddo
end
```

**Auto-parallelization Environment Variables**
Auto-parallelization Threshold Control and Diagnostics

Threshold Control

The `-par_threshold{n}` option sets a threshold for the auto-parallelization of loops based on the probability of profitable execution of the loop in parallel. The value of n can be from 0 to 100. The default value is 75. This option is used for loops whose computation work volume cannot be determined at compile-time. The threshold is usually relevant when the loop trip count is unknown at compile-time.

The `-par_threshold{n}` option has the following versions and functionality:

- **Default**: `-par_threshold` is not specified in the command line, which is the same as when `-par_threshold0` is specified. The loops get auto-parallelized regardless of computation work volume, that is, parallelize always.

- `-par_threshold100`: loops get auto-parallelized only if profitable parallel execution is almost certain.

- The intermediate 1 to 99 values represent the percentage probability for profitable speed-up. For example, n=50 would mean: parallelize only if there is a 50% probability of the code speeding up if executed in parallel.

- The default value of n is n=75 (or `-par_threshold75`). When `-par_threshold` is used on the command line without a number, the default value passed is 75.

The compiler applies a heuristic that tries to balance the overhead of creating multiple threads versus the amount of work available to be shared amongst the threads.

**Diagnostics**

The `-par_report{0|1|2|3}` option controls the auto-parallelizer's diagnostic levels.
0, 1, 2, or 3 as follows:

-par_report0 = no diagnostic information is displayed.

-par_report1 = indicates loops successfully auto-parallelized (default). Issues a "LOOP AUTO-PARALLELIZED" message for parallel loops.

-par_report2 = indicates successfully auto-parallelized loops as well as unsuccessful loops.

-par_report3 = same as 2 plus additional information about any proven or assumed dependences inhibiting auto-parallelization (reasons for not parallelizing).

Example of Parallelization Diagnostics Report

Example below shows an output generated by -par_report3 as a result from the command:

prompt> ifl -c /Qparallel /Qpar_report3 myprog.f90

where the program myprog.f90 is as follows:

```fortran
program myprog
    integer a(10000), q
    C Assumed side effects
    do i=1,10000
        a(i) = foo(i)
    enddo
    C Actual dependence
    do i=1,10000
        a(i) = a(i-1) + i
    enddo
end
```

Example of-par_report Output

```
program myprog
    procedure: myprog
    serial loop: line 5: not a parallel candidate due to statement at line 6
    serial loop: line 9 flow data dependence from line 10 to line 10, due to "a"
```

12 Lines Compiled

Troubleshooting Tips
- Use `-par_threshold0` to see if the compiler assumed there was not enough computational work
- Use `-par_report3` to view diagnostics
- Use `!DIR$ PARALLEL` directive to eliminate assumed data dependencies
- Use `-ipo` to eliminate assumed side-effects done to function calls.

### Debugging Multithreaded Programs

The debugging of multithreaded program discussed in this section applies to both the OpenMP Fortran API and the Intel Fortran parallel compiler directives. When a program uses parallel decomposition directives, you must take into consideration that the bug might be caused either by an incorrect program statement or it might be caused by an incorrect parallel decomposition directive. In either case, the program to be debugged can be executed by multiple threads simultaneously.

To debug the multithreaded programs, you can use:

- Intel Debugger for IA-32 and Intel Debugger for Itanium-based applications (idb)
- Intel Fortran Compiler debugging options and methods; in particular, [Compiling Source Lines with Debugging Statements](#)
- Intel parallelization extension routines for low-level debugging.
- VTune(TM) Performance Analyzer to define the problematic areas.

Other best known debugging methods and tips include:

- Correct the program in single-threaded, uni-processor environment
- Statically analyze locks
- Use trace statement (such as `print` statement)
- Think in parallel, make very few assumptions
- Step through your code
- Make sense of threads and callstack information
- Identify the primary thread
- Know what thread you are debugging
• Single stepping in one thread does not mean single stepping in others

• Watch out for context switch

**Debugger Limitations for Multithread Programs**

Debuggers such as Intel Debugger for IA-32 and Intel Debugger for Itanium-based applications support the debugging of programs that are executed by multiple threads. However, the currently available versions of such debuggers do not directly support the debugging of parallel decomposition directives, and therefore, there are limitations on the debugging features.

Some of the new features used in OpenMP are not yet fully supported by the debuggers, so it is important to understand how these features work to know how to debug them. The two problem areas are:

• Multiple entry points

• Shared variables

You can use routine names (for example, padd) and entry names (for example, _PADD, ___PADD_6__par_loop0). FORTRAN Compiler, by default, first mangles lower/mixed case routine names to upper case. For example, pAdD() becomes PADD(), and this becomes entry name by adding one underscore. The secondary entry name mangling happens after that. That's why "__par_loop" part of the entry name stays as lower case. Debugger for some reason didn't take the upper case routine name "PADD" to set the breakpoint. Instead, it accepted the lower case routine name "padd".

**Debugging Parallel Regions**

The compiler implements a parallel region by enabling the code in the region and putting it into a separate, compiler-created entry point. Although this is different from outlining – the technique employed by other compilers, that is, creating a subroutine, – the same debugging technique can be applied.

**Constructing an Entry-point Name**

The compiler-generated parallel region entry point name is constructed with a concatenation of the following strings:

• "__" character

• entry point name for the original routine (for example, _parallel)

• "_" character

• line number of the parallel region
• __par_region for OpenMP parallel regions (!$OMP PARALLEL)

__par_loop for OpenMP parallel loops (!$OMP PARALLEL DO),

__par_section for OpenMP parallel sections (!$OMP PARALLEL SECTIONS)

• sequence number of the parallel region (for each source file, sequence number starts from zero.)

**Debugging Code with Parallel Region**

Example 1 illustrates the debugging of the code with parallel region. Example 1 is produced by this command:

```bash
ifc -openmp -g -O0 -S file.f90
```

Let us consider the code of subroutine `parallel` in Example 1.

```
subroutine parallel
integer id, OMP_GET_THREAD_NUM
$OMP PARALLEL PRIVATE(id)
id = OMP_GET_THREAD_NUM()
$OMP END PARALLEL
end
```

The parallel region is at line 3. The compiler created two entry points: `parallel_` and `___parallel_3__par_region0`. The first entry point corresponds to the subroutine `parallel()`, while the second entry point corresponds to the OpenMP parallel region at line 3.

**Example 1 Debuging Code with Parallel Region**

<table>
<thead>
<tr>
<th>Machine Code Listing of the Subroutine <code>parallel()</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>.globl parallel_</td>
</tr>
<tr>
<td>parallel_:</td>
</tr>
<tr>
<td>.B1.1: #Preds ..B1.0</td>
</tr>
<tr>
<td>.LN1:</td>
</tr>
<tr>
<td>pushl %ebp #1.0</td>
</tr>
<tr>
<td>movl %esp, %ebp #1.0</td>
</tr>
<tr>
<td>subl $44, %esp #1.0</td>
</tr>
<tr>
<td>pushl %edi #1.0</td>
</tr>
<tr>
<td>movl $.2.1_2_kmmpc_loc_struct_pack.0, (%esp) #1.0</td>
</tr>
<tr>
<td>call __kmmpc_global_thread_num #1.0</td>
</tr>
<tr>
<td># LOE eax</td>
</tr>
</tbody>
</table>


..B1.21:  # Preds ..B1.1
addl $4, %esp #1.0
movl %eax, -44(%ebp) #1.0
   # LOE
..B1.2:  # Preds ..B1.21
movl -44(%ebp), %eax #1.0
movl %eax, -24(%ebp) #1.0
..LN2:
push %edi #3.0
movl $.2.1_2_kmpc_loc_struct_pack.1, (%esp) #3.0
call __kmpc_ok_to_fork #3.0
   # LOE eax
..B1.22:  # Preds ..B1.2
addl $4, %esp #3.0
movl %eax, -40(%ebp) #3.0
   # LOE
..B1.3:  # Preds ..B1.22
movl -40(%ebp), %eax #3.0
testl %eax, %eax #3.0
jne ..B1.7  # Prob 50% #3.0
   # LOE
..B1.4:  # Preds ..B1.3
addl $-8, %esp #3.0
movl $.2.1_2_kmpc_loc_struct_pack.1, (%esp) #3.0
movl -24(%ebp), %eax #3.0
movl %eax, 4(%esp) #3.0
call __kmpc_serialized_parallel #3.0
   # LOE
..B1.23:  # Preds ..B1.4
addl $8, %esp #3.0
   # LOE
..B1.5:  # Preds ..B1.23
addl $-8, %esp #3.0
lea -24(%ebp), %eax #3.0
movl %eax, (%esp) #3.0
movl $___kmpv_zeroparallel__0, 4(%esp) #3.0
call _parallel__3__par_region0 #3.0
   # LOE
..B1.24:  # Preds ..B1.5
addl $8, %esp #3.0
   # LOE
..B1.6:  # Preds ..B1.24
addl $-8, %esp #3.0
movl $.2.1_2_kmpc_loc_struct_pack.1, (%esp) #3.0
movl -24(%ebp), %eax #3.0
movl %eax, 4(%esp) #3.0
call __kmpc_end_serialized_parallel #3.0
   # LOE
..B1.25:       # Preds ..B1.6
addl           $8, %esp          #3.0
jmp            ..B1.8            # LOE          #3.0
            # Prob 100%
            #3.0
..B1.7:        # Preds ..B1.3
addl           $-12, %esp        #3.0
movl           $.2.1_2_kmpc_loc_struct_pack.1, (%esp) #3.0
movl           $0, 4(%esp)       #3.0
movl           $_parallel___3__par_region0, 8(%esp) #3.0
call           __kmpc_fork_call   #3.0
            # LOE
..B1.26:        # Preds ..B1.7
addl           $12, %esp         #3.0
            # LOE
..B1.8:        # Preds ..B1.26 ..B1.25
            # LOE
..LN3:
pushl          %edi              #6.0
movl           $.2.1_2_kmpc_loc_struct_pack.2, (%esp) #6.0
call           __kmpc_ok_to_fork  #6.0
            # LOE eax
..B1.27:        # Preds ..B1.8
addl           $4, %esp          #6.0
movl           %eax, -36(%ebp)    #6.0
            # LOE
..B1.9:        # Preds ..B1.27
movl           -36(%ebp), %eax   #6.0
testl          %eax, %eax         #6.0
jne            ..B1.13            # Prob 50%   #6.0
            # LOE
..B1.10:       # Preds ..B1.9
addl           $-8, %esp         #6.0
movl           $.2.1_2_kmpc_loc_struct_pack.2, (%esp) #6.0
movl           -24(%ebp), %eax   #6.0
movl           %eax, 4(%esp)     #6.0
call           __kmpc_serialized_parallel #6.0
            # LOE
..B1.28:        # Preds ..B1.10
addl           $8, %esp          #6.0
            # LOE
..B1.11:       # Preds ..B1.28
addl           $-8, %esp         #6.0
lea            -24(%ebp), %eax   #6.0
movl           %eax, (%esp)      #6.0
movl           __kmpv_zeroparallel__1, 4(%esp) #6.0
call           _parallel__6__par_region1 #6.0
            # LOE
..B1.29:       # Preds ..B1.11
addl           $8, %esp          #6.0
..B1.12: # Preds ..B1.29
addl $-8, %esp #6.0
movl $.2.1_2_kmpc_loc_struct_pack.2, (%esp) #6.0
movl -24(%ebp), %eax #6.0
movl %eax, 4(%esp) #6.0
call __kmpc_end_serialized_parallel #6.0

..B1.30: # Preds ..B1.12
addl $8, %esp #6.0
jmp ..B1.14 # Prob 100% #6.0

..B1.13: # Preds ..B1.9
addl $-12, %esp #6.0
movl $.2.1_2_kmpc_loc_struct_pack.2, (%esp) #6.0
movl $0, 4(%esp) #6.0
movl _parallel__6__par_region1, 8(%esp) #6.0
call __kmpc_fork_call #6.0

..B1.31: # Preds ..B1.13
addl $12, %esp #6.0

..B1.14: # Preds ..B1.31 ..B1.30
..LN4:
leave #9.0
ret #9.0

.type parallel_,@function
.size parallel_, -parallel_
.globl _parallel__3__par_region0
_parallel__3__par_region0:
# parameter 1: 8 + %ebp
# parameter 2: 12 + %ebp
..B1.15: # Preds ..B1.0
pushl %ebp #9.0
movl %esp, %ebp #9.0
subl $44, %esp #9.0
..LN5:
call omp_get_thread_num_
        # LOE eax
        # LOE
..B1.32: # Preds ..B1.15
movl %eax, -32(%ebp) #4.0

..B1.16: # Preds ..B1.32
movl -32(%ebp), %eax #4.0
movl %eax, -20(%ebp) #4.0
..LN6:
leave #9.0
Debugging at this level is just like debugging a program that uses POSIX threads directly. Breakpoints can be set in the threaded code just like any other routine. With GNU debugger, breakpoints can be set to source-level routine names (such as parallel). Breakpoints can also be set to entry point names (such as parallel__3__par_region0). Note that Intel Fortran Compiler for Linux converted the upper case Fortran subroutine name to the lower case one.

Debugging Multiple Threads

When in a debugger, you can switch from one thread to another. Each thread has its own program counter so each thread can be in a different place in the code. Example 2 shows a Fortran subroutine `PADD()`. A breakpoint can be set at the entry point of OpenMP parallel region.

Source listing of the Subroutine `PADD()`

```
ret  # LOE
.type _parallel__3__par_region0, @function
.size
_parallel__3__par_region0, .parallel__3__par_region0
.globl _parallel__6__par_region1
_parallel__6__par_region1:
# parameter 1: 8 + %ebp
# parameter 2: 12 + %ebp
.B1.17:  # Preds ..B1.0
  pushl  %ebp  #9.0
  movl  %esp, %ebp  #9.0
  subl  $44, %esp  #9.0
  .LN7:
  call  omp_get_thread_num_
  # LOE eax
  .B1.33:  # Preds ..B1.17
  movl  %eax, -28(%ebp)  #7.0
  # LOE
  .B1.18:  # Preds ..B1.33
  movl  -28(%ebp), %eax  #7.0
  movl  %eax, -16(%ebp)  #7.0
  .LN8:
  leave  #9.0
  ret  #9.0
.align 4,0x90
# mark_end;
```
The Call Stack Dumps

The first call stack below is obtained by breaking at the entry to subroutine PADD using GNU debugger. At this point, the program has not executed any OpenMP regions, and therefore has only one thread. The call stack shows a system runtime __libc_start_main function calling the Fortran main program parallel(), and parallel() calls subroutine padd(). When the program is executed by more than one thread, you can switch from one thread to another. The second and the third call stacks are obtained by breaking at the entry to the parallel region. The call stack of master contains the complete call sequence. At the top of the call stack is _padd__6__par_loop0(). Invocation of a threaded entry point involves a layer of Intel OpenMP library function calls (that is, functions with __kmp prefix). The call stack of the worker thread contains a partial call sequence that begins with a layer of Intel OpenMP library function calls.

ERRATA: GNU debugger sometimes fails to properly unwind the call stack of the immediate caller of Intel OpenMP library function __kmpc_fork_call().

Call Stack Dump of Master Thread upon Entry to Subroutine PADD

Switching from One Thread to Another
Call Stack Dump of Master Thread upon Entry to Parallel Region

Call Stack Dump of Worker Thread upon Entry to Parallel Region

Example 2  Debugging Code Using Multiple Threads with Shared Variables

<table>
<thead>
<tr>
<th>Subroutine PADD() Machine Code Listing</th>
</tr>
</thead>
<tbody>
<tr>
<td>.globl padd_</td>
</tr>
<tr>
<td>padd_:</td>
</tr>
<tr>
<td># parameter 1: 8 + %ebp</td>
</tr>
<tr>
<td># parameter 2: 12 + %ebp</td>
</tr>
<tr>
<td># parameter 3: 16 + %ebp</td>
</tr>
<tr>
<td># parameter 4(n): 20 + %ebp</td>
</tr>
<tr>
<td>..B1.1:</td>
</tr>
<tr>
<td># Preds ..B1.0</td>
</tr>
<tr>
<td>..LN1:</td>
</tr>
<tr>
<td>pushl %ebp</td>
</tr>
<tr>
<td>movl %esp, %ebp</td>
</tr>
<tr>
<td>subl $208, %esp</td>
</tr>
<tr>
<td>movl %ebx, -4(%ebp)</td>
</tr>
<tr>
<td>pushl %edi</td>
</tr>
<tr>
<td>movl $.2.1_2_kmpc_loc_struct_pack.0, (%esp)</td>
</tr>
<tr>
<td>call __kmpc_global_thread_num</td>
</tr>
<tr>
<td># LOE eax</td>
</tr>
<tr>
<td>..B1.34:</td>
</tr>
<tr>
<td># Preds ..B1.1</td>
</tr>
<tr>
<td>addl $4, %esp</td>
</tr>
<tr>
<td>movl %eax, -28(%ebp)</td>
</tr>
<tr>
<td># LOE</td>
</tr>
<tr>
<td>..B1.2:</td>
</tr>
<tr>
<td># Preds ..B1.34</td>
</tr>
<tr>
<td>movl -28(%ebp), %eax</td>
</tr>
<tr>
<td>movl %eax, -208(%ebp)</td>
</tr>
<tr>
<td>movl $4, %eax</td>
</tr>
<tr>
<td>movl %eax, -184(%ebp)</td>
</tr>
<tr>
<td>movl %eax, -188(%ebp)</td>
</tr>
<tr>
<td>movl 20(%ebp), %eax</td>
</tr>
</tbody>
</table>
movl (%eax), %eax         #1.0
movl %eax, -24(%ebp)      #1.0
testl %eax, %eax          #1.0
jg ..B1.5                # Prob 50%
                      # LOE
..B1.3:                  # Preds ..B1.2
        # LOE
movl $0, -24(%ebp)       #1.0
                      # LOE
..B1.5:                  # Preds ..B1.2 ..B1.3
movl -24(%ebp), %eax    #1.0
movl %eax, -164(%ebp)    #1.0
movl $1, %eax           #1.0
movl %eax, -176(%ebp)    #1.0
movl %eax, -168(%ebp)    #1.0
movl 20(%ebp), %edx     #1.0
movl (%edx), %edx        #1.0
movl %edx, -172(%ebp)     #1.0
movl -164(%ebp), %edx    #1.0
movl %edx, -192(%ebp)     #1.0
movl 8(%ebp), %edx      #1.0
movl %edx, -196(%ebp)     #1.0
movl $4, -204(%ebp)      #1.0
movl -204(%ebp), %edx   #1.0
negl %edx               #1.0
addl -196(%ebp), %edx    #1.0
movl %edx, -200(%ebp)    #1.0
movl %eax, -180(%ebp)    #1.0
movl -192(%ebp), %eax  #1.0
testl %eax, %eax        #1.0
jg ..B1.8                # Prob 50%
                      # LOE
..B1.6:                  # Preds ..B1.5
movl -172(%ebp), %eax  #1.0
testl %eax, %eax        #1.0
jg ..B1.8                # Prob 50%
              # LOE
..B1.7:                  # Preds ..B1.6
movl $0, -172(%ebp)    #1.0
                      # LOE
..B1.8:                  # Preds ..B1.6 ..B1.7 ..B1.5
movl $4, %eax           #1.0
movl %eax, -140(%ebp)    #1.0
movl %eax, -144(%ebp)    #1.0
movl $1, %edx           #1.0
movl %edx, -132(%ebp)    #1.0
movl %edx, -124(%ebp)    #1.0
movl 20(%ebp), %ecx    #1.0
movl (%ecx), %ecx       #1.0
movl  %ecx, -128(%ebp)  #1.0
movl  -164(%ebp), %ecx  #1.0
movl  %ecx, -148(%ebp)  #1.0
movl  12(%ebp), %ecx  #1.0
movl  %ecx, -152(%ebp)  #1.0
movl  %eax, -160(%ebp)  #1.0
movl  -160(%ebp), %eax  #1.0
negl  %eax  #1.0
addl  -152(%ebp), %eax  #1.0
movl  %eax, -156(%ebp)  #1.0
movl  $0, -128(%ebp)  #1.0
movl  $4, %eax  #1.0
movl  %eax, -100(%ebp)  #1.0
movl  %eax, -104(%ebp)  #1.0
movl  $1, %edx  #1.0
movl  %edx, -92(%ebp)  #1.0
movl  %edx, -84(%ebp)  #1.0
movl  20(%ebp), %ecx  #1.0
movl  (%ecx), %ecx  #1.0
movl  %ecx, -88(%ebp)  #1.0
movl  -164(%ebp), %ecx  #1.0
movl  %ecx, -108(%ebp)  #1.0
movl  16(%ebp), %ecx  #1.0
movl  %ecx, -112(%ebp)  #1.0
movl  %eax, -120(%ebp)  #1.0
movl  -120(%ebp), %eax  #1.0
negl  %eax  #1.0
addl  -112(%ebp), %eax  #1.0
movl  %eax, -116(%ebp)  #1.0
movl  %edx, -96(%ebp)  #1.0
movl  -108(%ebp), %eax  #1.0
testl  %eax, %eax  #1.0
jg    ..B1.11     # Prob 50%  #1.0
    # LOE

..B1.9: # Preds ..B1.8
        movl  -128(%ebp), %eax  #1.0
testl  %eax, %eax  #1.0
jg    ..B1.11     # Prob 50%  #1.0
        # LOE

..B1.10:  # Preds ..B1.9
        movl  $0, -128(%ebp)  #1.0
        # LOE

..B1.11:  #
Preds ..B1.9 ..B1.10 ..B1.8
        movl  $4, %eax  #1.0
movl  %eax, -100(%ebp)  #1.0
movl  %eax, -104(%ebp)  #1.0
movl  $1, %edx  #1.0
movl  %edx, -92(%ebp)  #1.0
movl  %edx, -84(%ebp)  #1.0
movl  20(%ebp), %ecx  #1.0
movl  (%ecx), %ecx  #1.0
movl  %ecx, -88(%ebp)  #1.0
movl  -164(%ebp), %ecx  #1.0
movl  %ecx, -108(%ebp)  #1.0
movl  16(%ebp), %ecx  #1.0
movl  %ecx, -112(%ebp)  #1.0
movl  %eax, -120(%ebp)  #1.0
movl  -120(%ebp), %eax  #1.0
negl  %eax  #1.0
addl  -112(%ebp), %eax  #1.0
movl  %eax, -116(%ebp)  #1.0
movl  %edx, -96(%ebp)  #1.0
movl  -108(%ebp), %eax  #1.0
testl  %eax, %eax  #1.0
jg    ..B1.14     # Prob 50%  #1.0
        # LOE
..B1.12:  # Preds ..B1.11
movl  -88(%ebp), %eax  #1.0
testl %eax, %eax  #1.0
jg   ..B1.14  # Prob 50%
       # LOE

..B1.13:  # Preds ..B1.12
movl   $0, -88(%ebp)  #1.0
       # LOE

..B1.14:
       # Preds ..B1.12 ..B1.13 ..B1.11
..LN2:
pushl %edi  #6.0
movl $.2.1_2_kmpc_loc_struct_pack.1, (%esp)  #6.0
call __kmpc_ok_to_fork  #6.0
       # LOE eax

..B1.35:  # Preds ..B1.14
addl $4, %esp  #6.0
movl %eax, -20(%ebp)  #6.0
       # LOE

..B1.15:  # Preds ..B1.35
movl -20(%ebp), %eax  #6.0
testl %eax, %eax  #6.0
jne   ..B1.19  # Prob 50%
       # LOE

..B1.16:
       # Preds ..B1.15
addl $-8, %esp  #6.0
movl $.2.1_2_kmpc_loc_struct_pack.1, (%esp)  #6.0
movl -208(%ebp), %eax  #6.0
movl %eax, 4(%esp)  #6.0
call __kmpc_serialized_parallel  #6.0
       # LOE

..B1.36:  # Preds ..B1.16
addl $8, %esp  #6.0
       # LOE

..B1.17:  # Preds ..B1.36
addl $-24, %esp  #6.0
lea -208(%ebp), %eax  #6.0
movl %eax, (%esp)  #6.0
movl $___kmpv_zeropadd__0, 4(%esp)  #6.0
movl -196(%ebp), %eax  #6.0
movl %eax, 8(%esp)  #6.0
movl -152(%ebp), %eax  #6.0
movl %eax, 12(%esp)  #6.0
movl -112(%ebp), %eax  #6.0
movl %eax, 16(%esp)  #6.0
lea 20(%ebp), %eax  #6.0
movl %eax, 20(%esp)  #6.0
call _padd__6__par_loop0  #6.0
# LOE
..B1.37: # Preds ..B1.17
addl $24, %esp #6.0
# LOE
..B1.18: # Preds ..B1.37
addl $-8, %esp #6.0
movl $.2.1_2_kmpc_loc_struct_pack.1, (%esp) #6.0
movl -208(%ebp), %eax #6.0
movl %eax, 4(%esp) #6.0
call __kmpc_end_serialized_parallel #6.0
# LOE
..B1.38: # Preds ..B1.18
addl $8, %esp #6.0
jmp ..B1.31 # Prob 100% #6.0
# LOE
..B1.19: # Preds ..B1.15
addl $-28, %esp #6.0
movl $.2.1_2_kmpc_loc_struct_pack.1, (%esp) #6.0
movl $4, 4(%esp) #6.0
movl $_padd__6__par_loop0, 8(%esp) #6.0
movl -196(%ebp), %eax #6.0
movl %eax, 12(%esp) #6.0
movl -152(%ebp), %eax #6.0
movl %eax, 16(%esp) #6.0
movl -112(%ebp), %eax #6.0
movl %eax, 20(%esp) #6.0
lea 20(%ebp), %eax #6.0
movl %eax, 24(%esp) #6.0
call __kmpc_fork_call #6.0
# LOE
..B1.39: # Preds ..B1.19
addl $28, %esp #6.0
jmp ..B1.31 # Prob 100% #6.0
# LOE
..B1.20: # Preds ..B1.30
movl $1, %eax #6.0
movl %eax, -72(%ebp) #6.0
..LN3:
movl -80(%ebp), %edx #10.0
..LN4:
movl %edx, -68(%ebp) #6.0
..LN5:
movl -80(%ebp), %edx #10.0
..LN6:
movl %edx, -64(%ebp) #6.0
movl $0, -60(%ebp) #6.0
movl %eax, -56(%ebp) #6.0
addl $-36, %esp #6.0
movl $.2.1_2_kmpc_loc_struct_pack.I, (%esp) #6.0
movl -8(%ebp), %edx #6.0
movl %edx, 4(%esp) #6.0
movl $34, 8(%esp) #6.0
lea -60(%ebp), %edx #6.0
movl %edx, 12(%esp) #6.0
lea -72(%ebp), %edx #6.0
movl %edx, 16(%esp) #6.0
lea -68(%ebp), %edx #6.0
movl %edx, 20(%esp) #6.0
lea -68(%ebp), %edx #6.0
movl %edx, 24(%esp) #6.0
movl %eax, 28(%esp) #6.0
movl %eax, 32(%esp) #6.0
call __kmpc_for_static_init_4 #6.0

# LOE
..B1.40: # Preds ..B1.20
addl $36, %esp #6.0
# LOE
..B1.21: # Preds ..B1.40
movl -72(%ebp), %eax #6.0
movl -64(%ebp), %edx #6.0
cmpl %edx, %eax #6.0
jg ..B1.26 # Prob 50% #6.0
# LOE
..B1.22: # Preds ..B1.21
movl -68(%ebp), %eax #6.0
movl -64(%ebp), %edx #6.0
cmpl %edx, %eax #6.0
jg ..B1.24 # Prob 50% #6.0
# LOE
..B1.23: # Preds ..B1.22
movl -68(%ebp), %eax #6.0
movl %eax, -16(%ebp) #6.0
jmp ..B1.25 # Prob 100% #6.0
# LOE
..B1.24: # Preds ..B1.22
movl -64(%ebp), %eax #6.0
movl %eax, -16(%ebp) #6.0
# LOE
..B1.25: # Preds ..B1.24 ..B1.23
movl -16(%ebp), %eax #6.0
movl %eax, -68(%ebp) #6.0
movl -72(%ebp), %eax #6.0
movl %eax, -76(%ebp) #6.0
jmp ..B1.27 # Prob 100% #6.0
# LOE
..B1.26: # Preds ..B1.28 ..B1.21
addl $-8, %esp  #6.0
movl $.2.1_2_kmpc_loc_struct_pack.1, (%esp)  #6.0
movl -8(%ebp), %eax  #6.0
movl %eax, 4(%esp)  #6.0
call __kmpc_for_static_fini  #6.0

..B1.41:  # LOE
    addl $8, %esp  #6.0
    jmp ..B1.31  # Prob 100%  #6.0
        # LOE
..B1.27:  # Preds ..B1.28 ..B1.25
..LN7:
call omp_get_thread_num_  #8.0
        # LOE eax
..B1.42:  # Preds ..B1.27
    movl %eax, -12(%ebp)  #8.0
        # LOE
..B1.28:  # Preds ..B1.42
    movl -12(%ebp), %eax  #8.0
    movl %eax, -52(%ebp)  #8.0
..LN8:
    movl -76(%ebp), %eax  #9.0
..LN9:
    movl 16(%ebp), %edx  #6.0
..LN10:
    movl -76(%ebp), %ecx  #9.0
..LN11:
    movl 20(%ebp), %ebx  #6.0
..LN12:
    movl -4(%ebx,%ecx,4), %ecx  #9.0
    addl -4(%edx,%eax,4), %ecx  #9.0
    addl -52(%ebp), %ecx  #9.0
    movl -76(%ebp), %eax  #9.0
..LN13:
    movl 24(%ebp), %edx  #6.0
..LN14:
    movl %ecx, -4(%edx,%eax,4)  #9.0
..LN15:
    incl -76(%ebp)  #10.0
    movl -76(%ebp), %eax  #10.0
    movl -68(%ebp), %edx  #10.0
cmpl %edx, %eax  #10.0
jle ..B1.27  # Prob 50%  #10.0
jmp ..B1.26  # Prob 100%  #10.0
        # LOE

.type padd_,@function
.size padd_,.-padd_
.globl _padd__6__par_loop0
When a variable appears in a `PRIVATE`, `FIRSTPRIVATE`, `LASTPRIVATE`, or `REDUCTION` clause on some block, the variable is made private to the parallel region by redeclaring it in the block. `SHARED` data, however, is not declared in the threaded code. Instead, it gets its declaration at the routine level. At the machine code level, these shared variables become incoming subroutine call arguments to the threaded entry points (such as `_padd_6__par_loop0`).

In Example 2, the entry point `_padd_6__par_loop0` has six incoming parameters. The corresponding OpenMP parallel region has four shared variables. First two parameters (parameters 1 and 2) are reserved for the compiler's use, and each of the remaining four

```fortran
_padd_6__par_loop0:
# parameter 1: 8 + %ebp
# parameter 2: 12 + %ebp
# parameter 3: 16 + %ebp
# parameter 4: 20 + %ebp
# parameter 5: 24 + %ebp
# parameter 6: 28 + %ebp
..B1.30:              # Preds ..B1.0
..LN16:
pushl  %ebp            #13.0
movl   %esp, %ebp      #13.0
subl   $208, %esp      #13.0
movl   %ebx, -4(%ebp)  #13.0
..LN17:
movl   8(%ebp), %eax  #6.0
movl   (%eax), %eax    #6.0
movl   %eax, -8(%ebp)  #6.0
movl   28(%ebp), %eax  #6.0
..LN18:
movl   (%eax), %eax   #7.0
movl   (%eax), %eax    #7.0
movl   %eax, -80(%ebp) #7.0
movl   $1, -76(%ebp)   #7.0
movl   -80(%ebp), %eax #7.0
testl  %eax, %eax      #7.0
jg     ..B1.20         # Prob 50% #7.0
      # LOE
..B1.31:                #
Preds ..B1.41 ..B1.39 ..B1.38 ..B1.30
..LN19:
movl   -4(%ebp), %ebx  #13.0
leave   #13.0
ret     #13.0
.align 4,0x90
# mark_end;
```

**Debugging Shared Variables**

When a variable appears in a `PRIVATE`, `FIRSTPRIVATE`, `LASTPRIVATE`, or `REDUCTION` clause on some block, the variable is made private to the parallel region by redeclaring it in the block. `SHARED` data, however, is not declared in the threaded code. Instead, it gets its declaration at the routine level. At the machine code level, these shared variables become incoming subroutine call arguments to the threaded entry points (such as `_padd_6__par_loop0`).

In Example 2, the entry point `_padd_6__par_loop0` has six incoming parameters. The corresponding OpenMP parallel region has four shared variables. First two parameters (parameters 1 and 2) are reserved for the compiler's use, and each of the remaining four
parameters corresponds to one shared variable. These four parameters exactly match the last four parameters to \texttt{__kmpc_fork__call()} in the machine code of \texttt{PADD}.

\textbf{Note}

The \texttt{FIRSTPRIVATE}, \texttt{LASTPRIVATE}, and \texttt{REDUCTION} variables also require shared variables to get the values into or out of the parallel region.

Due to the lack of support in debuggers, the correspondence between the shared variables (in their original names) and their contents cannot be seen in the debugger at the threaded entry point level. However, you can still move to the call stack of one of the subroutines and examine the contents of the variables at that level. This technique can be used to examine the contents of shared variables. In Example 2, contents of the shared variables \texttt{A}, \texttt{B}, \texttt{C}, and \texttt{N} can be examined if you move to the call stack of \texttt{PARALLEL()}.

## Vectorization

The vectorizer is a component of the Intel® Fortran Compiler that automatically uses SIMD instructions in the MMX(TM), SSE, and SSE2 instruction sets. The vectorizer detects operations in the program that can be done in parallel, and then converts the sequential operations like one SIMD instruction that processes 2, 4, 8 or up to 16 elements in parallel, depending on the data type.

This section provides options description, guidelines, and examples for Intel® Fortran Compiler vectorization implemented by IA-32 compiler only. For additional information, see \texttt{Publications on Compiler Optimizations}.

The following list summarizes this section contents.

- Descriptions of compiler \texttt{options} to control vectorization
- Vectorization Key Programming Guidelines
- Discussion and general guidelines on vectorization levels:
  - automatic vectorization
  - vectorization with user intervention
- Examples demonstrating typical vectorization issues and resolutions

The Intel compiler supports a variety of directives that can help the compiler to generate effective vector instructions. See \texttt{compiler directives supporting vectorization}.

## Vectorizer Options
Vectorization is an IA-32-specific feature and can be summarized by the command line options described in the following tables. Vectorization depends upon the compiler’s ability to disambiguate memory references. Certain options may enable the compiler to do better vectorization. These options can enable other optimizations in addition to vectorization. When a \(-x{M\mid K\mid W}\) or \(-ax{M\mid K\mid W}\) is used and \(-O2\) (which is ON by default) is also in effect, the vectorizer is enabled. The \(-Qx{M\mid K\mid W}\) or \(-Qax{M\mid K\mid W}\) options enable vectorizer with \(-O1\) and \(-O3\) options also.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-x{M\mid K\mid W})</td>
<td>Generate specialized code to run exclusively on the processors supporting the extensions indicated by {M\mid K\mid W}. See Exclusive Specialized Code with (-x{i\mid M\mid K\mid W}) for details.</td>
</tr>
<tr>
<td>(-ax{M\mid K\mid W})</td>
<td>Generates, in a single binary, code specialized to the extensions specified by {M\mid K\mid W} and also generic IA-32 code. The generic code is usually slower. See Specialized Code with (-ax{i\mid M\mid K\mid W}) for details.</td>
</tr>
<tr>
<td>(-vec_report{0\mid 1\mid 2\mid 3\mid 4\mid 5})</td>
<td>Controls the diagnostic messages from the vectorizer, see subsection that follows the table. Default: (-vec_report1)</td>
</tr>
</tbody>
</table>

**Vectorization Reports**

The \(-vec_report{0\mid 1\mid 2\mid 3\mid 4\mid 5}\) options directs the compiler to generate the vectorization reports with different level of information as follows:

- \(-vec_report0\): no diagnostic information is displayed
- \(-vec_report1\): display diagnostics indicating loops successfully vectorized (default)
- \(-vec_report2\): same as \(-vec_report1\), plus diagnostics indicating loops not successfully vectorized
- \(-vec_report3\): same as \(-vec_report2\), plus additional information about any proven or assumed dependences
- \(-vec_report4\): indicate non-vectorized loops
- \(-vec_report5\): indicate non-vectorized loops and the reason why they were not
vectorized.

**Usage with Other Options**

The vectorization reports are generated in the final compilation phase when executable is generated. Therefore if you use the `-c` option and a `-vec_report{n}` option in the command line, no report will be generated.

If you use `-c`, `-ipo` and `-x{M|K|W}` or `-ax{M|K|W}` and `-vec_report{n}`, the compiler issues a warning and no report is generated.

To produce a report when using the above mentioned options, you need to add the `-ipo_obj` option. The combination of `-c` and `-ipo_obj` produces a single file compilation, and hence does generate object code, and eventually a report is generated.

The following commands generate vectorization report:

```plaintext
prompt> ifc -x{M|K|W} -vec_report3 file.f

prompt> ifc -x{M|K|W} -ipo -ipo_obj -vec_report3 file.f

prompt> ifc -c -x{M|K|W} -ipo -ipo_obj -vec_report3 file.f
```

**Loop Parallelization and Vectorization**

Combining the `-parallel` and `-x{M|K|W}` options instructs the compiler to attempt both automatic loop parallelization and automatic loop vectorization in the same compilation. In most cases, the compiler will consider outermost loops for parallelization and innermost loops for vectorization. If deemed profitable, however, the compiler may even apply loop parallelization and vectorization to the same loop. See Guidelines for Effective Auto-parallelization Usage and Vectorization Key Programming Guidelines.

Note that in some rare cases successful loop parallelization (either automatically or by means of OpenMP directives) may affect the messages reported by the compiler for a non-vectorizable loop in a non-intuitive way.

**Vectorization Key Programming Guidelines**

The goal of vectorizing compilers is to exploit single-instruction multiple data (SIMD) processing automatically. Users can help however by supplying the compiler with additional information; for example, directives. Review these guidelines and restrictions, see code examples in further topics, and check them against your code to eliminate ambiguities that prevent the compiler from achieving optimal vectorization.
Guidelines

You will often need to make some changes to your loops.

For loop bodies -

Use:

- Straight-line code (a single basic block)
- Vector data only; that is, arrays and invariant expressions on the right hand side of assignments. Array references can appear on the left hand side of assignments.
- Only assignment statements

Avoid:

- Function calls
- Unvectorizable operations (other than mathematical)
- Mixing vectorizable types in the same loop
- Data-dependent loop exit conditions
- Loop unrolling (compiler does it)
- Decomposing one loop with several statements in the body into several single-statement loops.

Restrictions

Vectorization depends on the two major factors:

- **Hardware.** The compiler is limited by restrictions imposed by the underlying hardware. In the case of Streaming SIMD Extensions, the vector memory operations are limited to stride-1 accesses with a preference to 16-byte-aligned memory references. This means that if the compiler abstractly recognizes a loop as vectorizable, it still might not vectorize it for a distinct target architecture.

- **Style.** The style in which you write source code can inhibit optimization. For example, a common problem with global pointers is that they often prevent the compiler from being able to prove that two memory references refer to distinct locations. Consequently, this prevents certain reordering transformations.

Many stylistic issues that prevent automatic vectorization by compilers are found in loop structures. The ambiguity arises from the complexity of the keywords, operators, data
references, and memory operations within the loop bodies.

However, by understanding these limitations and by knowing how to interpret diagnostic messages, you can modify your program to overcome the known limitations and enable effective vectorization. The following sections summarize the capabilities and restrictions of the vectorizer with respect to loop structures.

Data Dependence

Data dependence relations represent the required ordering constraints on the operations in serial loops. Because vectorization rearranges the order in which operations are executed, any auto-vectorizer must have at its disposal some form of data dependence analysis.

An example where data dependencies prohibit vectorization is shown below. In this example, the value of each element of an array is dependent on the value of its neighbor that was computed in the previous iteration.

```
Data-dependent Loop
REAL DATA(0:N)
INTEGER I
DO I=1, N-1
  DATA(I) = DATA(I-1) * 0.25 + DATA(I) * 0.5 + DATA(I+1) * 0.25
END DO
```

The loop in the above example is not vectorizable because the WRITE to the current element DATA(I) is dependent on the use of the preceding element DATA(I-1), which has already been written to and changed in the previous iteration. To see this, look at the access patterns of the array for the first two iterations as shown below.

```
Data Dependence Vectorization Patterns
I=1: READ DATA (0)
    READ DATA (1)
    READ DATA (2)
    WRITE DATA (1)
I=2: READ DATA(1)
    READ DATA (2)
    READ DATA (3)
    WRITE DATA (2)
```

In the normal sequential version of this loop, the value of DATA(1) read from during the second iteration was written to in the first iteration. For vectorization, it must be possible to do the iterations in parallel, without changing the semantics of the original loop.

Data Dependence Analysis
Data dependence analysis involves finding the conditions under which two memory accesses may overlap. Given two references in a program, the conditions are defined by:

- whether the referenced variables may be aliases for the same (or overlapping) regions in memory, and, for array references
- the relationship between the subscripts

For IA-32, data dependence analyzer for array references is organized as a series of tests, which progressively increase in power as well as in time and space costs. First, a number of simple tests are performed in a dimension-by-dimension manner, since independence in any dimension will exclude any dependence relationship. Multidimensional arrays references that may cross their declared dimension boundaries can be converted to their linearized form before the tests are applied. Some of the simple tests that can be used are the fast greatest common divisor (GCD) test and the extended bounds test. The GCD test proves independence if the GCD of the coefficients of loop indices cannot evenly divide the constant term. The extended bounds test checks for potential overlap of the extreme values in subscript expressions. If all simple tests fail to prove independence, we eventually resort to a powerful hierarchical dependence solver that uses Fourier-Motzkin elimination to solve the data dependence problem in all dimensions. For more details of data dependence theory and data dependence analysis, refer to the Publications on Compiler Optimizations.

## Loop Constructs

Loops can be formed with the usual `DO-ENDDO` and `DO WHILE`, or by using a `GOTO` and a label. However, the loops must have a single entry and a single exit to be vectorized. Following are the examples of correct and incorrect usages of loop constructs.

<table>
<thead>
<tr>
<th>Correct Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUBROUTINE FOO (A, B, C)</td>
</tr>
<tr>
<td>DIMENSION A(100), B(100), C(100)</td>
</tr>
<tr>
<td>INTEGER I</td>
</tr>
<tr>
<td>I = 1</td>
</tr>
<tr>
<td>DO WHILE (I .LE. 100)</td>
</tr>
<tr>
<td>A(I) = B(I) * C(I)</td>
</tr>
<tr>
<td>IF (A(I) .LT. 0.0) A(I) = 0.0</td>
</tr>
<tr>
<td>I = I + 1</td>
</tr>
<tr>
<td>ENDDO</td>
</tr>
<tr>
<td>RETURN</td>
</tr>
<tr>
<td>END</td>
</tr>
</tbody>
</table>
Loop Exit Conditions

Loop exit conditions determine the number of iterations that a loop executes. For example, fixed indexes for loops determine the iterations. The loop iterations must be countable; that is, the number of iterations must be expressed as one of the following:

- a constant
- a loop invariant term
- a linear function of outermost loop indices

Loops whose exit depends on computation are not countable. Examples below show countable and non-countable loop constructs.

### Incorrect Usage

```
SUBROUTINE FOO (A, B, C)
DIMENSION A(100), B(100), C(100)
INTEGER I
I = 1
DO WHILE (I .LE. 100)
    A(I) = B(I) * C(I)
C The next statement allows early exit from the loop and prevents vectorization of the loop.
    IF (A(I) .LT. 0.0) GOTO 10
    I = I + 1
ENDDO
10 CONTINUE
RETURN
END
```

### Correct Usage for Countable Loop, Example 1

```
SUBROUTINE FOO (A, B, C, N, LB)
DIMENSION A(N), B(N), C(N)
INTEGER N, LB, I, COUNT
! Number of iterations is "N - LB + 1"
COUNT = N
DO WHILE (COUNT .GE. LB)
    A(I) = B(I) * C(I)
ENDDO
RETURN
END
```
TYPES OF LOOP VECTORIZED

For integer loops, the 64-bit MMX(TM) technology and 128-bit Streaming SIMD Extensions (SSE) provide SIMD instructions for most arithmetic and logical operators on 32-bit, 16-bit, and 8-bit integer data types. Vectorization may proceed if the final precision of integer wrap-around arithmetic will be preserved. A 32-bit shift-right operator, for instance, is not vectorized in 16-bit mode if the final stored value is a 16-bit integer. Because the MMX(TM) and SSE instruction sets are not fully orthogonal (shifts on byte operands, for instance, are not supported), not all integer operations can actually be vectorized.

For loops that operate on 32-bit single-precision and 64-bit double-precision floating-point numbers, SSE provides SIMD instructions for the arithmetic operators '+', '-', '*', and '/'. In addition, SSE provides SIMD instructions for the binary MIN and MAX and unary SQRT.
operators. SIMD versions of several other mathematical operators (like the trigonometric functions SIN, COS, TAN) are supported in software in a vector mathematical runtime library that is provided with the Intel® Fortran Compiler, of which the compiler takes advantage.

**Stripmining and Cleanup**

The compiler automatically strip-mines your loop and generates a cleanup loop.

<table>
<thead>
<tr>
<th>Stripmining and Cleanup Loops</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before Vectorization</strong></td>
</tr>
<tr>
<td>$i = 1$</td>
</tr>
<tr>
<td>do while $(i \leq n)$</td>
</tr>
<tr>
<td>$a(i) = b(i) + c(i)$ ! Original loop code</td>
</tr>
<tr>
<td>$i = i + 1$</td>
</tr>
<tr>
<td>end do</td>
</tr>
</tbody>
</table>

| **After Vectorization**      |
| !The vectorizer generates the following two loops |
| $i = 1$                      |
| do while $(i < (n - \text{mod}(n,4)))$ |
| ! Vector strip-mined loop. |
| $a(i:i+3) = b(i:i+3) + c(i:i+3)$ |
| $i = i + 4$                  |
| end do                      |
| do while $(i \leq n)$        |
| $a(i) = b(i) + c(i)$ !Scalar clean-up loop |
| $i = i + 1$                  |
| end do                      |

**Statements in the Loop Body**

The vectorizable operations are different for floating point and integer data.

**Floating-point Array Operations**

The statements within the loop body may be REAL operations (typically on arrays). Arithmetic operations supported are addition, subtraction, multiplication, division, negation, square root, MAX, MIN, and mathematical functions such as SIN and COS. Note that conversion to/from some types of floats is not valid. Operation on DOUBLE PRECISION types is not valid, unless optimizing for an Intel®
Pentium® 4 and Intel® Xeon™ processors’ system, and Intel® Pentium® M processor’s, using the -xW or -axW compiler option.

**Integer Array Operations**

The statements within the loop body may be arithmetic or logical operations (again, typically for arrays). Arithmetic operations are limited to such operations as addition, subtraction, ABS, MIN, and MAX. Logical operations include bitwise AND, OR, and XOR operators. You can mix data types only if the conversion can be done without a loss of precision. Some example operators where you can mix data types are multiplication, shift, or unary operators.

**Other Operations**

No statements other than the preceding floating-point and integer operations are permitted. The loop body cannot contain any function calls other than the ones described above.

**Vectorization Examples**

This section contains simple examples of some common issues in vector programming.

**Argument Aliasing: A Vector Copy**

The loop in the example of a vector copy operation does not vectorize because the compiler cannot prove that DEST(A(I)) and DEST(B(I)) are distinct.

```fortran
SUBROUTINE VEC_COPY
  (DEST, A, B, LEN)
DIMENSION DEST(*)
INTEGER A(*), B(*)
INTEGER LEN, I
DO I=1,LEN
  DEST(A(I)) = DEST(B(I))
END DO
RETURN
END
```

**Data Alignment**

A 16-byte or greater data structure or array should be aligned so that the beginning of each structure or array element is aligned in a way that its base address is a multiple of 16.

The Misaligned Data Crossing 16-Byte Boundary figure shows the effect of a data cache
unit (DCU) split due to misaligned data. The code loads the misaligned data across a 16-byte boundary, which results in an additional memory access causing a six- to twelve-cycle stall. You can avoid the stalls if you know that the data is aligned and you specify to assume alignment.

**Misaligned Data Crossing 16-Byte Boundary**

<table>
<thead>
<tr>
<th>16 Byte Boundaries</th>
<th>16 Byte Boundaries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Misaligned Data</td>
</tr>
</tbody>
</table>

After vectorization, the loop is executed as shown in figure below.

**Vector and Scalar Clean-up Iterations**

<table>
<thead>
<tr>
<th>2 vector iterations</th>
<th>2 clean-up iterations in scalar mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>i = 1, 2, 3, 4</td>
<td>i = 5, 6, 7, 8</td>
</tr>
<tr>
<td>i = 9, 10</td>
<td></td>
</tr>
</tbody>
</table>

Both the vector iterations A(1:4) = B(1:4); and A(5:8) = B(5:8); can be implemented with aligned moves if both the elements A(1) and B(1) are 16-byte aligned.

⚠️ **Caution**

If you specify the vectorizer with incorrect alignment options, the compiler will generate code with unexpected behavior. Specifically, using aligned moves on unaligned data, will result in an illegal instruction exception!

**Alignment Strategy**

The compiler has at its disposal several alignment strategies in case the alignment of data structures is not known at compile-time. A simple example is shown below (several other strategies are supported as well). If in the loop shown below the alignment of A is unknown, the compiler will generate a prelude loop that iterates until the array reference, that occurs the most, hits an aligned address. This makes the alignment properties of A known, and the vector loop is optimized accordingly. In this case, the vectorizer applies dynamic loop peeling, a specific Intel® Fortran feature.
Original loop:

```fortran
SUBROUTINE DOIT(A)
REAL A(100) ! alignment of argument A is unknown
DO I = 1, 100
A(I) = A(I) + 1.0
ENDDO
END SUBROUTINE
```

Aligning Data

```
! The vectorizer will apply dynamic loop peeling as follows:
SUBROUTINE DOIT(A)
REAL A(100)
! let P be (A%16) where A is address of A(1)
IF (P .NE. 0) THEN
P = (16 - P) /4 ! determine runtime peeling factor
DO I = 1, P
A(I) = A(I) + 1.0
ENDDO
ENDIF
! Now this loop starts at a 16-byte boundary,
! and will be vectorized accordingly
DO I = P + 1, 100
A(I) = A(I) + 1.0
ENDDO
END SUBROUTINE
```

Loop Interchange and Subscripts: Matrix Multiply

Matrix multiplication is commonly written as shown in the following example.

```
DO I=1, N
DO J=1, N
DO K=1, N
C(I,J) = C(I,J) + A(I,K)*B(K,J)
END DO
END DO
END DO
```
The use of $B(K, J)$, is not a stride-1 reference and therefore will not normally be vectorizable. If the loops are interchanged, however, all the references will become stride-1 as in the Matrix Multiplication with Stride-1 example that follows.

⚠️ Note

Interchanging is not always possible because of dependencies, which can lead to different results.

<table>
<thead>
<tr>
<th>Matrix Multiplication with Stride-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO J=1, N</td>
</tr>
<tr>
<td>DO K=1, N</td>
</tr>
<tr>
<td>DO I=1, N</td>
</tr>
<tr>
<td>C(I, J) = C(I, J) + A(I, K) * B(K, J)</td>
</tr>
<tr>
<td>ENDDO</td>
</tr>
<tr>
<td>ENDDO</td>
</tr>
<tr>
<td>ENDDO</td>
</tr>
</tbody>
</table>

For additional information, see [Publications on Compiler Optimizations](#).
Optimization Support Features

This section describes the Intel® Fortran features such as directives, intrinsics, runtime library routines and various utilities which enhance your application performance in support of compiler optimizations. These features are Intel Fortran language extensions that enable you optimize your source code directly. This section includes examples of optimizations supported by Intel extended directives and intrinsics or library routines that enhance and/or help analyze performance.

For complete detail of the Intel® Fortran Compiler directives and examples of their use, see Appendix A in the Intel® Fortran Programmer's Reference. For intrinsic procedures, see Chapter 1, "Intrinsic Procedures," in the Intel® Fortran Libraries Reference.

A special topic describes options that enable you to generate optimization reports for major compiler phases and major optimizations. The optimization report capability is used for Itanium®-based applications only.

Compiler Directives

This section discusses the Intel® Fortran language extended directives that enhance optimizations of application code, such as software pipelining, loop unrolling, prefetching and vectorization. For complete list, descriptions and code examples of the Intel® Fortran Compiler directives, see Appendix A in the Intel® Fortran Programmer's Reference.

Pipelining for Itanium®-based Applications

The SWP | NOSWP directives indicate preference for a loop to get software-pipelined or not. The SWP directive does not help data dependence, but overrides heuristics based on profile counts or lop-sided control flow.

The syntax for this directive is:

CDIR$ SWP or !DIR$ SWP

CDIR$ NOSWP or !DIR$ NOSWP

The software pipelining optimization triggered by the SWP directive applies instruction scheduling to certain innermost loops, allowing instructions within a loop to be split into different stages, allowing increased instruction level parallelism. This can reduce the impact of long-latency operations, resulting in faster loop execution. Loops chosen for software pipelining are always innermost loops that do not contain procedure calls that are not inlined. Because the optimizer no longer considers fully unrolled loops as innermost loops, fully unrolling loops can allow an additional loop to become the innermost loop (see —
unroll[n]). You can request and view the optimization report to see whether software pipelining was applied (see Optimizer Report Generation).

### Loop Count and Loop Distribution

#### LOOP COUNT (N) Directive

The LOOP COUNT (n) directive indicates the loop count is likely to be n.

The syntax for this directive is:

CDIR$ LOOP COUNT(n) or !DIR$ LOOP COUNT(n)

where n is an integer constant.

The value of loop count affects heuristics used in software pipelining, vectorization and loop-transformations.

```
CDIR$ LOOP COUNT (10000)
do i = 1, m
  b(i) = a(i) +1 ! This is likely to enable
  ! the loop to get software-pipelined
endo
```

#### Loop Distribution Directive

The DISTRIBUTION POINT directive indicates to compiler a preference of performing loop distribution.

The syntax for this directive is:

CDIR$ DISTRIBUTION POINT or !DIR$ DISTRIBUTION POINT
Loop distribution may cause large loops be distributed into smaller ones. This may enable more loops to get software-pipelined. If the directive is placed inside a loop, the distribution is performed after the directive and any loop-carried dependency is ignored. If the directive is placed before a loop, the compiler will determine where to distribute and data dependency is observed. Currently only one distribute directive is supported if it is placed inside the loop.

### LOOP UNROLLING SUPPORT

The **UNROLL** directive tells the compiler how many times to **unroll a counted loop**.

The syntax for this directive is:

```
CDIR$ UNROLL or !DIR$ UNROLL

CDIR$ UNROLL [n] or !DIR$ UNROLL [n]

CDIR$ NOUNROLL or !DIR$ NOUNROLL
```

where **n** is an integer constant. The range of **n** is 0 through 255.
The **UNROLL** directive must precede the **do** statement for each **do** loop it affects.

If \( n \) is specified, the optimizer unrolls the loop \( n \) times. If \( n \) is omitted or if it is outside the allowed range, the optimizer assigns the number of times to unroll the loop.

The **UNROLL** directive overrides any setting of loop unrolling from the command line.

Currently, the directive can be applied only for the innermost loop nest. If applied to the outer loop nests, it is ignored. The compiler generates correct code by comparing \( n \) and the loop count.

<table>
<thead>
<tr>
<th>UNROLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDIR$ UNROLL(4)</td>
</tr>
<tr>
<td>do i = 1, m</td>
</tr>
<tr>
<td>b(i) = a(i) + 1</td>
</tr>
<tr>
<td>d(i) = c(i) + 1</td>
</tr>
<tr>
<td>enddo</td>
</tr>
</tbody>
</table>

### Prefetching Support

The **PREFETCH** and **NOPREFETCH** directives assert that the data prefetcheds be generated or not generated for some memory references. This affects the heuristics used in the compiler.

The syntax for this directive is:

CDIR$ PREFETCH or !DIR$ PREFETCH

CDIR$ NOPREFETCH or !DIR$ NOPREFETCH

CDIR$ PREFETCH a,b or !DIR$ PREFETCH a,b

CDIR$ NOPREFETCH a,b or !DIR$ NOPREFETCH a,b

If loop includes expression \( a(j) \), placing **PREFETCH** \( a \) in front of the loop, instructs the compiler to insert prefetches for \( a(j + d) \) within the loop. \( d \) is determined by the compiler. This directive is supported when option `-O3` is on.

<table>
<thead>
<tr>
<th>PREFETCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDIR$ NOPREFETCH c</td>
</tr>
<tr>
<td>CDIR$ PREFETCH a</td>
</tr>
<tr>
<td>do i = 1, m</td>
</tr>
<tr>
<td>b(i) = a(c(i)) + 1</td>
</tr>
<tr>
<td>enddo</td>
</tr>
</tbody>
</table>
Vectorization Support (IA-32)

The directives discussed in this topic support vectorization and are used for IA-32 applications only.

**IVDEP Directive**

The compiler supports IVDEP directive which instructs the compiler to ignore assumed vector dependences. Use this directive when you know that the assumed loop dependences are safe to ignore.

For example, if the expression $j \geq 0$ is always true in the code fragment below, the IVDEP directive can communicate this information to the compiler. This directive informs the compiler that the conservatively assumed loop-carried flow dependences for values $j < 0$ can be safely ignored:

```
!DIR$ IVDEP
do i = 1, 100
  a(i) = a(i+j)
enddo
```

**Note**

The proven dependences that prevent vectorization are not ignored, only assumed dependences are ignored.

The syntax for the directive is:

```
CDIR$IVDEP
!DIR$IVDEP
```

The usage of the directive differs depending on the loop form, see examples below.

<table>
<thead>
<tr>
<th>Loop 1</th>
<th>Loop 2</th>
</tr>
</thead>
</table>
| Do i  
  a(*) = a(*) + 1  
  a(*) = a(*) + 1  
  enddo | Do i  
  a(*) = a(*) + 1  
  enddo |

For loops of the form 1, use old values of $a$, and assume that there is no loop-carried flow
dependencies from DEF to USE.

For loops of the form 2, use new values of \( a \), and assume that there is no loop-carried anti-depencies from USE to DEF.

In both cases, it is valid to distribute the loop, and there is no loop-carried output dependency.

**Example 1**

```fortran
CDIR$IVDEP
do j=1,n
  a(j) = a(j+m) + 1
enddo
```

**Example 2**

```fortran
CDIR$IVDEP
do j=1,n
  a(j) = b(j) +1
  b(j) = a(j+m) + 1
enddo
```

Example 1 ignores the possible backward dependencies and enables the loop to get software pipelined.

Example 2 shows possible forward and backward dependencies involving array \( a \) in this loop and creating a dependency cycle. With IVDEP, the backward dependencies are ignored.

**IVDEP** has options: \( \text{IVDEP:LOOP} \) and \( \text{IVDEP:BACK} \). The \( \text{IVDEP:LOOP} \) option implies no loop-carried dependencies. The \( \text{IVDEP:BACK} \) option implies no backward dependencies.

The **IVDEP** directive is also used for Itanium®-based applications.

For more details on the **IVDEP** directive, see Appendix A in the *Intel® Fortran Programmer’s Reference*.

**Overriding Vectorizer's Efficiency Heuristics**

In addition to **IVDEP** directive, there are three directives that can be used to override the efficiency heuristics of the vectorizer:

```fortran
!DIR$VECTOR ALWAYS
!DIR$NOVECTOR
!DIR$VECTOR ALIGNED
!DIR$VECTOR UNALIGNED
```

The **VECTOR ALWAYS** directive overrides the efficiency heuristics of the vectorizer, but it only works if the loop can actually be vectorized, that is: use IVDEP to ignore assumed
dependences.

**The VECTOR ALWAYS and NOVECTOR Directives**

The VECTOR ALWAYS directive can be used to override the default behavior of the compiler in the following situation. Vectorization of non-unit stride references usually does not exhibit any speedup, so the compiler defaults to not vectorizing loops that have a large number of non-unit stride references (compared to the number of unit stride references). The following loop has two references with stride 2. Vectorization would be disabled by default, but the directive overrides this behavior.

<table>
<thead>
<tr>
<th>Vector Aligned</th>
</tr>
</thead>
<tbody>
<tr>
<td>!DIR$ VECTOR ALWAYS</td>
</tr>
<tr>
<td>do i = 1, 100, 2</td>
</tr>
<tr>
<td>a(i) = b(i)</td>
</tr>
<tr>
<td>enddo</td>
</tr>
</tbody>
</table>

If, on the other hand, avoiding vectorization of a loop is desirable (if vectorization results in a performance regression rather than improvement), the NOVECTOR directive can be used in the source text to disable vectorization of a loop. For instance, the Intel® Compiler vectorizes the following example loop by default. If this behavior is not appropriate, the NOVECTOR directive can be used, as shown below.

<table>
<thead>
<tr>
<th>NOVECTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>!DIR$ NOVECTOR</td>
</tr>
<tr>
<td>do i = 1, 100</td>
</tr>
<tr>
<td>a(i) = b(i) + c(i)</td>
</tr>
<tr>
<td>enddo</td>
</tr>
</tbody>
</table>

**The VECTOR ALIGNED and UNALIGNED Directives**

Like VECTOR ALWAYS, these directives also override the efficiency heuristics. The difference is that the qualifiers UNALIGNED and ALIGNED instruct the compiler to use, respectively, unaligned and aligned data movement instructions for all array references. This disables all the advanced alignment optimizations of the compiler, such as determining alignment properties from the program context or using dynamic loop peeling to make references aligned.

**Note**

The directives VECTOR [ALWAYS, UNALIGNED, ALIGNED] should be used with care. Overriding the efficiency heuristics of the compiler should only be done if the programmer is absolutely sure the vectorization will improve performance. Furthermore, instructing the compiler to implement all array references with aligned data movement instructions will cause a runtime exception in case some of the access patterns are actually unaligned.

**Compiler Intrinsics**
Intel® Fortran supports all standard Fortran intrinsic procedures and in addition, provides Intel-specific intrinsic procedures to extend the functionality of the language. Intel Fortran intrinsic procedures are provided in the library libintrins.lib. See Chapter 1, "Intrinsic Procedures," in the Intel® Fortran Libraries Reference.

This topic provides examples of the Intel-extended intrinsics that are helpful in developing efficient applications.

**Cache Size Intrinsic (Itanium® Compiler)**

Intrinsic cashesize(n) is used only with Intel® Itanium® Compiler. cashesize(n) returns the size in kilobytes of the cache at level n; 1 represents the first level cache. Zero is returned for a nonexistent cache level.

This intrinsic can be used in many scenarios where application programmer would like to tailor their algorithms for target processor's cache hierarchy. For example, an application may query the cache size and use it to select block sizes in algorithms that operate on matrices.

```fortran
subroutine foo (level)
    integer level
    if (cachesize(level) > threshold)
        call big_bar()
    else
        call small_bar()
    end if
end subroutine
```

**Timing Your Application**

One of the performance indicators is your application timing. Use the time command to provide information about program performance. The following considerations apply to timing your application:

- Run program timings when other users are not active. Your timing results can be affected by one or more CPU-intensive processes also running while doing your timings.

- Try to run the program under the same conditions each time to provide the most accurate results, especially when comparing execution times of a previous version of the same program. Use the same CPU system (model, amount of memory, version of the operating system, and so on) if possible.

- If you do need to change systems, you should measure the time using the same version of the program on both systems, so you know each system's effect on your
timings.

- For programs that run for less than a few seconds, run several timings to ensure that the results are not misleading. Overhead functions like loading shared libraries might influence short timings considerably.

Using the form of the \texttt{time} command that specifies the name of the executable program provides the following:

- The elapsed, real, or "wall clock" time, which will be greater than the total charged actual CPU time.

- Charged actual CPU time, shown for both system and user execution. The total actual CPU time is the sum of the actual user CPU time and actual system CPU time.

**Example**

In the following example timings, the sample program being timed displays the following line:

\begin{verbatim}
Average of all the numbers is: 4368488960.000000
\end{verbatim}

Using the Bourne shell, the following program timing reports that the program uses 1.19 seconds of total actual CPU time (0.61 seconds in actual CPU time for user program use and 0.58 seconds of actual CPU time for system use) and 2.46 seconds of elapsed time:

\begin{verbatim}
$ time a.out
Average of all the numbers is: 4368488960.000000
real 0m2.46s
user 0m0.61s
sys 0m0.58s
\end{verbatim}

Using the C shell, the following program timing reports 1.19 seconds of total actual CPU time (0.61 seconds in actual CPU time for user program use and 0.58 seconds of actual CPU time for system use), about 4 seconds (0:04) of elapsed time, the use of 28% of available CPU time, and other information:

\begin{verbatim}
% time a.out
Average of all the numbers is:
  4368488960.000000
0.61u 0.58s 0:04 28% 78+424k 9+5io
\end{verbatim}
Using the bash shell, the following program timing reports that the program uses 1.19 seconds of total actual CPU time (0.61 seconds in actual CPU time for user program use and 0.58 seconds of actual CPU time for system use) and 2.46 seconds of elapsed time:

```
[user@system user]$ time ./a.out
Average of all the numbers is:
  4368488960.000000
elapsed 0m2.46s
user   0m0.61s
sys    0m0.58s
```

Timings that show a large amount of system time may indicate a lot of time spent doing I/O, which might be worth investigating.

If your program displays a lot of text, you can redirect the output from the program on the time command line. Redirecting output from the program will change the times reported because of reduced screen I/O.

For more information, see `time(1)`.

In addition to the `time` command, you might consider modifying the program to call routines within the program to measure execution time. For example, use the Intel Fortran intrinsic procedures, such as `SECONDS`, `DCLOCK`, `CPU_TIME`, `SYSTEM_CLOCK`, and `DATE_AND_TIME`. See "Intrinsic Procedures" in the Intel® Fortran Libraries Reference.

## Optimizer Report Generation

The Intel® Fortran Compiler provides options to generate and manage optimization reports.

- `--opt_report` generates optimizations report and places it in a file specified in `--opt_report_file filename`. If `--opt_report_file` is not specified, `--opt_report` directs the report to `stderr`. The default is OFF: no reports are generated.

- `--opt_report_file filename` generates optimizations report and directs it to a file specified in `filename`.

- `--opt_report_level{min|med|max}` specifies the detail level of the optimizations report. The `min` argument provides the minimal summary and the `max` the full report. The default is `--opt_report_level min`.
- `-opt_report_routine_routine_substring` generates reports from all routines with names containing the `substring` as part of their name. If not specified, reports from all routines are generated. The default is to generate reports for all routines being compiled.

**Specifying Optimizations to Generate Reports**

The compiler can generate reports for an optimizer you specify in the `phase` argument of the `-opt_report_phase phase` option.

The option can be used multiple times on the same command line to generate reports for multiple optimizers.

Currently, the reports for the following optimizers are supported:

<table>
<thead>
<tr>
<th>Optimizer Logical Name</th>
<th>Optimizer Full Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ipo</td>
<td>Interprocedural Optimizer</td>
</tr>
<tr>
<td>hlo</td>
<td>High-level Language Optimizer</td>
</tr>
<tr>
<td>ilo</td>
<td>Intermediate Language Scalar Optimizer</td>
</tr>
<tr>
<td>ecg</td>
<td>Itanium Compiler Code Generator</td>
</tr>
<tr>
<td>all</td>
<td>All optimizers</td>
</tr>
</tbody>
</table>

When one of the above logical names for optimizers are specified all reports from that optimizer will be generated. For example, `-opt_report_phase ipo` and `-opt_report_phase ecg` generate reports from the interprocedural optimizer and the code generator.

Each of the optimizers can potentially have specific optimizations within them. Each of these optimizations are prefixed with the optimizer's logical name. For example:

<table>
<thead>
<tr>
<th>Optimizer_optimization</th>
<th>Full Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ipo_inl</td>
<td>Interprocedural Optimizer, inline expansion of functions</td>
</tr>
<tr>
<td>ipo_cp</td>
<td>Interprocedural Optimizer, copy propagation</td>
</tr>
<tr>
<td>hlo_unroll</td>
<td>High-level Language Optimizer, loop unrolling</td>
</tr>
<tr>
<td>hlo_prefetch</td>
<td>High-level Language Optimizer, prefetching</td>
</tr>
<tr>
<td>ilo_copy_propagation</td>
<td>Intermediate Language Scalar Optimizer, copy propagation</td>
</tr>
</tbody>
</table>
Command Syntax Example

The following command generates a report for the Itanium Compiler Code Generator (ecg):

```
prompt> efc -c -opt_report -opt_report_phase ecg myfile.f
```

where:

- `-c` tells the compiler to stop at generating the object code, not linking
- `-opt_report` invokes the report generator
- `-opt_report_phase ecg` indicates the phase (ecg) for which to generate the report; the space between the option and the phase is optional.

The entire name for a particular optimization within an optimizer need not be specified in full, just a few characters is sufficient. All optimization reports that have a matching prefix with the specified optimizer are generated. For example, if `-opt_report_phase ilo_co` is specified, a report from both the constant propagation and the copy propagation are generated.

The Availability of Report Generation

The `-opt_report_help` option lists the logical names of optimizers and optimizations that are currently available for report generation.

For **IA-32 systems**, the reports can be generated for:

- `ilo`
- `hlo` if `-O3` is on
- `ipo` if interprocedural optimizer is invoked with `-ip` or `-ipo`
- `all` the above optimizers if `-O3` and `-ip` or `-ipo` options are on

For **Itanium-based systems**, the reports can be generated for:

- `ilo`
- `ecg`
- `hlo` if `-O3` is on
• ipo if interprocedural optimizer is invoked with -ip or -ipo

• all the above optimizers if -O3 and -ip or -ipo options are on

⚠️ Note

If hlo or ipo report is requested, but the controlling option (-O3 or -ip--ipo, respectively) is not on, the compiler generates an empty report.
Libraries

Managing Libraries

You can determine the libraries for your applications by controlling the linker or by using the options described in this section. See library options summary.

The LD_LIBRARY_PATH environment variable contains a colon-separated list of directories that the linker will search for library (.a) files. If you want the linker to search additional libraries, you can add their names to the command line, to a response file, or to the configuration (.cfg) file. In each case, the names of these libraries are passed to the linker before these libraries:

- the libraries provided with the Intel® Fortran Compiler (libCEPCF90.a, libIEPCF90.a, libintrins.a, libF90.a, and the math library: libimf.a for both IA-32 compiler and libm.a for Itanium® compiler; libm.a is the math library provided with the gcc*)

- the default libraries that the compiler command always specifies are:

  libimf.a*
  libm.a
  libirc.a*
  libcxa.a*
  libcprts.a*
  libunwind.a*
  libc.a

  The ones marked with an "*" are provided by Intel.

For more information on response and configuration files, see Response Files and Configuration Files.

The linker uses the LD_LIBRARY_PATH variable to search for libraries. If you are compiling with a linker option that forces static libraries, it will look for those at compile time. Otherwise, it will look for shared libraries at runtime.

To specify a library name on the command line, you must first add the library’s path to the LD_LIBRARY_PATH environment variable. Then, to compile file.f and link it with the library libmine.a, for example, enter the following command:

**IA-32 applications:**

prompt>ifc file.f -lm

**Itanium®-based applications:**
prompt>efc file.f -lmine

The example above implies that the library resides in your path.

**The Order of Passing the Files to Linker**

The compiler passes files to the linker in the following order:

1. Object files and libraries are passed to the linker in the order specified on the command line.

2. Object files and libraries in the .cfg file will be processed before those on the command line. This means that putting library names in the .cfg file does not make much sense because the libraries will be processed before most object files are seen.

3. The **libimf.a**, **libF90.a**, **libintrinsics.a**, and **libIEPCF90.a** libraries.

4. The **libm.a** library is linked in just before **libc.a**, then **libc.a** libraries.

See the list of libraries that are installed with the Intel® Fortran Compiler for **IA-32 applications** and for **Itanium®-based applications**.

**Using the POSIX* and Portability Libraries**

Use the `-posixlib` option with the compiler to invoke the POSIX* bindings library **libposf90.a**. For a complete list of these functions see Chapter 3, "POSIX Functions" in the *Intel® Fortran Libraries Reference Manual*.

Use the `-Vaxlib` option with the compiler to invoke the VAX* compatibility functions **libpepcf90.a**. This also brings in the Intel's compatibility functions for Sun* and Microsoft*. For a complete list of these functions see Chapter 2, "Portability Functions" in the *Intel® Fortran Libraries Reference Manual*.

**Intel® Shared Libraries**

The Intel® Fortran Compiler (both IA-32 and Itanium® compilers) links the libraries statically at link time and dynamically at the run time, the latter as dynamically-shared objects (DSO).

By default, the libraries are linked as follows:

- Fortran, math and **libcprts.a** libraries are linked at link time, that is, statically.

- **libcxa.so** is linked dynamically to conform to C++ application binary interface (ABI).

- GNU and Linux* system libraries are linked dynamically.
Advantages of This Approach

This approach—

- Enables to maintain the same model for both IA-32 and Itanium compilers.
- Provides a model consistent with the Linux model where system libraries are dynamic and application libraries are static.
- The users have the option of using dynamic versions of our libraries to reduce the size of their binaries if desired.
- The users are licensed to distribute Intel-provided libraries.

The libraries *libcprts.a* and *libcxa.so* are C++ language support libraries used by Fortran when Fortran includes code written in C++.

Shared Library Options

The main options used with shared libraries are *-i_dynamic* and *-shared*.

The *-i_dynamic* compiler option directs the linker to use the shared object versions of the Intel-provided libraries dynamically. The comparison of the following commands illustrates the effects of this option.

1. `prompt> ifc myprog.f`

This command produces the following results (default):

- Fortran, math, *libirc.a*, and *libcprts.a* libraries are linked statically (at link time).
- Dynamic version of *libcxa.so* is linked at run time.

The statically linked libraries increase the size of the application binary, but do not need to be installed on the systems where the application runs.

2. `prompt> ifc -i_dynamic myprog.f`

This command links all of the above libraries dynamically. This has the advantage of reducing the size of the application binary, but it requires all the dynamic versions installed on the systems where the application runs.

The *-shared* option instructs the compiler to build a dynamically-shared object instead of an executable. For more details, refer to the *ld* man page documentation.
Math Libraries Overview

The libimf.a is the math library provided by Intel and libm.a is the math library provided with gcc*. Both of these libraries are linked in by default on IA-32 and Itanium® compilers. Both libraries are linked in because there are math functions supported by the GNU math library that are not in the Intel math library. This linking arrangement allows the GNU users to have all functions available when using ifc (or efc), with Intel optimized versions available when supported. libimf.a is linked in before libm.a. If you link in libm.a first, it will change the versions of the math functions that are used.

It is recommended that you place libimf.a and libm.a in the first directory specified in the LD_LIBRARY_PATH variable. The libimf.a and libm.a libraries are always linked with Fortran programs.

If you place libimf.a in a different directory, you need to set the the LD_LIBRARY_PATH variable to specify a list of directories, containing all other libraries; the directories in the list must be separated by semicolons.

IA-32 Compiler

For IA-32 Compiler, libimf.a contains both generic math routines and versions of the math routines optimized for special use with the Intel® Pentium® 4 and Intel® Xeon(TM) processors.

Itanium® Compiler

For Itanium Compiler, libimf.a is optimized for the use with Itanium® architecture. The Itanium compiler provides inlined version of the following math library primitives by using the following intrinsics: ALOG, DLOG, ALOG10, DLOG10, IEXP, DEXP, CEILING, and FLOOR. The compiler inlines these intrinsics and schedules the generated code with surrounding instructions. This can improve performance of typical floating-point applications.

Using Math Libraries with IA-32 Systems

Most of the routines in libm.a for IA-32 have been optimized for special use with the Intel® Pentium® 4 and Intel® Xeon(TM) processors. Generic versions are used when running on an IA-32 processor generation prior to Pentium 4 processor family.

To use your own version of the standard math functions without unresolved external errors, you must disable the automatic inline expansion by compiling your program with the -nolib_inline option, as described in Inline Expansion of Library Functions.

⚠️ Caution
A change of the default precision control or rounding mode (for example, by using the -pc32 flag or by user intervention) may affect the results returned by some of the mathematical functions.

**Optimized Math Library Primitives**

The optimized math libraries contain a package of functions, called primitives. The Intel Fortran Compiler calls these functions to implement numerous floating-point intrinsics and exponentiation. About half of the functions in the library from Intel are written in assembly language and optimized for program execution speed on an IA-32 architecture processor.

**Note**
The library primitives are not Fortran intrinsics. They are standard library calls used by the compiler to implement Intel Fortran language features.

Following is a list of math library primitives that have been optimized.

<table>
<thead>
<tr>
<th>Function</th>
<th>Function</th>
<th>Function</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>acos</td>
<td>cos</td>
<td>log10</td>
<td>sinh</td>
</tr>
<tr>
<td>asin</td>
<td>cosh</td>
<td>pow</td>
<td>sqrt</td>
</tr>
<tr>
<td>atan</td>
<td>exp</td>
<td>powf</td>
<td>tan</td>
</tr>
<tr>
<td>atan2</td>
<td>log</td>
<td>sin</td>
<td>tanh</td>
</tr>
</tbody>
</table>

The math library also provides the following non-optimized primitives.

<table>
<thead>
<tr>
<th>Function</th>
<th>Function</th>
<th>Function</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>acosh</td>
<td>copysign</td>
<td>fmod</td>
<td>gamma</td>
</tr>
<tr>
<td>asinh</td>
<td>erf, derf</td>
<td>fmodf</td>
<td>remainder</td>
</tr>
<tr>
<td>atanh</td>
<td>fabs</td>
<td>hypot</td>
<td>rint</td>
</tr>
<tr>
<td>cbrt</td>
<td>fabsf</td>
<td>j0</td>
<td>y0</td>
</tr>
<tr>
<td>ceil</td>
<td>floor</td>
<td>j1</td>
<td>y1</td>
</tr>
<tr>
<td>ceilf</td>
<td>floorf</td>
<td>jn</td>
<td>y2</td>
</tr>
</tbody>
</table>

**Programming with Math Library Primitives**

Primitives adhere to standard calling conventions, thus you can call them with other high-level languages as well as with assembly language. For Intel Fortran Compiler programs, specify the appropriate Fortran intrinsic name for arguments of type REAL and DOUBLE PRECISION. The compiler calls the appropriate single- or double-precision primitive based on the type of the argument you specify.

To use these functions, you have to write an INTERFACE block that specifies the ALIAS name of the function. The routine names in the math library are lower case.
IEEE* Floating-point Exceptions

The compiled code contains a set of floating-point exceptions required for compatibility with the IEEE numeric floating-point standard. The following floating-point exceptions are supported during numeric processing:

<table>
<thead>
<tr>
<th>Exception</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denormal</td>
<td>One of the floating-point operands has an absolute value that is too small to represent with full precision in the significand.</td>
</tr>
<tr>
<td>Zero Divide</td>
<td>The dividend is finite and the divisor is zero, but the correct answer has infinite magnitude.</td>
</tr>
<tr>
<td>Overflow</td>
<td>The resulting floating-point number is too large to represent.</td>
</tr>
<tr>
<td>Underflow</td>
<td>The resulting floating-point number (which is very close to zero) has an absolute value that is too small to represent even if a loss of precision is permitted in the significand (gradual underflow).</td>
</tr>
<tr>
<td>Inexact (Precision)</td>
<td>The resulting number is not represented exactly due to rounding or gradual underflow.</td>
</tr>
<tr>
<td>Invalid operation</td>
<td>Covers cases not covered by other exceptions. An invalid operation produces a quiet NaN (Not-a-Number).</td>
</tr>
</tbody>
</table>

**Denormal**

The denormal exception occurs if one or more of the operands is a denormal number. This exception is never regarded as an error.

**Divide-by-Zero Exception**

A divide-by-zero exception occurs for a floating-point division operation if the divisor is zero and the dividend is finite and non-zero. It also occurs for other operations in which the operands are finite and the correct answer is infinite.

When the divide by zero exception is masked, the result is +/-infinity. The following specific cases cause a zero-divide exception:

- \( \text{LOG}(0.0) \)
- \( \text{LOG10}(0.0) \)
- \( 0.0**x \), where \( x \) is a negative number
For the value of the flags, refer to the `ieee_flags()` function in your library manual and *Pentium® Processor Family Developer's Manual*, Volumes 1, 2, and 3.

**Overflow Exception**

An overflow exception occurs if the rounded result of a floating-point operation contains an exponent larger than the numeric processing unit can represent. A calculation with an infinite input number is not sufficient to cause an exception.

When the overflow exception is masked, the calculated result is +/-infinity or the +/-largest representable normal number depending on rounding mode. When the exception is not masked, a result with an accurate significand and a wrapped exponent is available to an exception handler.

**Underflow Exception**

The underflow exception occurs if the rounded result has an exponent that is too small to be represented using the floating-point format of the result.

If the underflow exception is masked, the result is represented by the smallest normal number, a denormal number, or zero. When the exception is not masked, a result with an accurate significand and a wrapped exponent is available to an exception handler.

**Inexact Exception**

The inexact exception occurs if the rounded result of an operation is not equal to the unrounded result.

It is important that the inexact exception remain masked at all times because many of the numeric library procedures return with an undefined inexact exception flag. If the inexact exception is masked, no special action is performed. When this exception is not masked, the rounded result is available to an exception handler.

**Invalid Operation Exception**

An invalid operation indicates that an exceptional condition not covered by one of the other exceptions has occurred. An invalid operation can be caused by any of the following situations:

- One or more of the operands is a signaling NaN or is in an unsupported format.
- One of the following invalid operations has been requested:
  
  \[(\pm)0.0/(\pm)0.0, (\pm)0.0*(\pm)\infty, (\pm)\infty-(\pm)\infty \circ (\pm)\infty/(\pm)\infty.\]
- The function **INT**, **NINT**, or **IRINT** is applied to an operand that is too large to fit into the requested **INTEGER*2** or **INTEGER*4** data types.

- A comparison of **.LT.**, **.LE.**, **.GT.**, or **.GE.** is applied to two operands that are unordered.

The invalid-operation exception can occur in any of the following functions:

- **SQRT(x)**, **LOG(x)**, or **LOG10(x)**, where x is less than zero.

- **ASIN(x)**, or **ACOS(x)** where |x|>1.

For any of the invalid-operation exceptions, the exception handler is invoked before the top of the stack changes, so the operands are available to the exception handler.

When invalid-operation exceptions are masked, the result of an invalid operation is a quiet NaN. Program execution proceeds normally using the quiet NaN result.

<table>
<thead>
<tr>
<th>Floating-point Result</th>
<th>The appearance of a quiet NaN as an operand results in a quiet NaN. Execution continues without an error. If both operands are quiet NaNs, the quiet NaN with the larger significand is used as the result. Thus, each quiet NaN is propagated through later floating-point calculations until it is ultimately ignored or referenced by an operation that delivers non-floating-point results.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formatted Output</td>
<td>On formatted output using a real edit descriptor, the field is filled with the &quot;?&quot; symbols to indicate the undefined (NaN) result. The A, Z, or B edit descriptor results in the ASCII, hexadecimal, or binary interpretation, respectively, of the internal representation of the NaN. No error is signaled for output of a NaN.</td>
</tr>
<tr>
<td>Logical Result</td>
<td>By definition, a NaN has no ordinal rank with respect to any other operand, even itself. Tests for equality (<strong>.EQ.</strong>) and inequality (<strong>.NE.</strong>) are the only Fortran relational operations for which results are defined for unordered operands. In these cases, program execution continues without error. Any other logical operation yields an undefined result when applied to NaNs, causing an invalid-operation error. The masked result is unpredictable.</td>
</tr>
<tr>
<td>Integer Result</td>
<td>Since no internal NaN representation exists for the <strong>INTEGER</strong> data type, an invalid-operation error is normally signaled. The masked result is the largest-magnitude negative integer for <strong>INTEGER*4</strong> or <strong>INTEGER*2</strong>. An <strong>INTEGER*1</strong> result is the value of an <strong>INTEGER*2</strong> intermediate result modulo 256.</td>
</tr>
</tbody>
</table>
Intel® Fortran Compiler provides a method to control the rounding mode, exception handling and other IEEE-related functions of the IA-32 processors using IEEE_FLG$ and IEEE_HANDLER library routines from the portability library. For details, see Chapter 2 in the Intel® Fortran Libraries Reference Manual.
Diagnostics and Messages

This section describes the diagnostic messages that the Intel® Fortran Compiler produces. These messages include various diagnostic messages for remarks, warnings, or errors. The compiler always displays any error message, along with the erroneous source line, on the standard error device. The messages also include the runtime diagnostics run for IA-32 compiler only.

The options that provide checks and diagnostic information must be specified when the program is compiled, but they perform checks or produce information when the program is run. See diagnostic options summary.

Runtime Diagnostics Overview

For IA-32 applications, the Intel® Fortran Compiler provides runtime diagnostic checks to aid debugging. The compiler provides a set of options that identify certain conditions commonly attributed to runtime failures.

You must specify the options when the program is compiled. However, they perform checks or produce information when the program is run. Postmortem reports provide additional diagnostics according to the detail you specify.

Runtime diagnostics are handled by IA-32 options only. The use of -O0 option turns any of them off. See the runtime check options summary.

Optional Runtime Checks

Runtime checks on the use of pointers, allocatable arrays and assumed-shape arrays are made with the runtime checks specified by the Intel® Fortran Compiler command line runtime diagnostic options listed below. The use of any of these options disables optimization.

The optional runtime check options are as follows:

<table>
<thead>
<tr>
<th>Option</th>
<th>Equivalent to: (-CA, -CB, -CS, -CU, -CV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-C</td>
<td>Equivalent to: (-CA, -CB, -CS, -CU, -CV)</td>
</tr>
</tbody>
</table>

Note

The -C option and its equivalents are available for IA-32 systems only.
Pointers, \(-\text{CA}\)

The selection of the \(-\text{CA}\) compile-time option has the following effect on the runtime checking of pointers:

- The association status of a pointer is checked whenever it is referenced. Error 460 as described in Runtime Errors will be reported at runtime if the pointer is disassociated: that is, if the pointer is nullified, de-allocated, or it is a pointer assigned to a disassociated pointer.

- The compile-time option combination of \(-\text{CA}\) and \(-\text{CU}\) also generates code to test whether a pointer is in the initially undefined state, that is, if it has never been associated or disassociated or allocated. If a pointer is initially undefined, then Error 461 as described in Runtime Errors will be reported at runtime if an attempt is made to use it. No test is made for dangling pointers (that is, pointers referencing memory locations which are no longer valid).

- The association status of pointers is not tested when the Fortran standard does not require the pointer to be associated, that is, in the following circumstances:
  
  - in a pointer assignment
  
  - as an argument to the associated intrinsic
- as an argument to the `present` intrinsic

- in the `nullify` statement

- as an actual argument associated with a formal argument which has the pointer attribute

**Allocatable Arrays**

The selection of the `-CA` compile-time option causes code to be generated to test the allocation status of an allocatable array whenever it is referenced, except when it is an argument to the `allocated` intrinsic function. Error 459 as described in Runtime Errors will be reported at runtime if an error is detected.

**Assumed-Shape Arrays**

The `-CA` option causes a validation check to be made, on entry to a procedure, on the definition status of an assumed-shape array. Error 462 as described in Runtime Errors will be reported at runtime if the array is disassociated or not allocated.

The compile-time option combination of `-CA` and `-CU` will additionally generate code to test whether, on entry to a procedure, the array is in the initially undefined state. If so, Error 463 as described in Runtime Errors.

**Array Subscripts, Character Substrings, –CB**

Specifying the compile-time option `-CB` causes a check at runtime that array subscript values, subscript values of elements selected from an array section, and character substring references are within bounds. Selection of the option causes code to be generated for each array or character substring reference in the program.

At runtime the code checks that the address computed for a referenced array element is within the address range delimited by the first element of the array and the last element of the array. Note that this check does not ensure that each subscript in a reference to an element of a multidimensional array or section is within bounds, only that the address of the element is within the address range of the array.

For assumed-size arrays, only the address of the first element of the array is used in the check; the address of the last element is unknown.

When `-CB` is selected, a check is also made that any character substring references are within the bounds of the character entity referenced.
Unassigned Variables, \( -\text{CU} \)

Specifying the compile-time option \( -\text{CU} \) causes unassigned variable checking to be enabled: that is, before an expression is evaluated at runtime, a check is normally made that any variables in the expression have previously been assigned values. If any has not, a runtime error results.

Some variables are not unassigned-checked, even when \( -\text{CU} \) has been selected:

- Variables of type character
- byte, integer(1) and logical(1) variables
- Variables of derived type, when the complete variable (not individual fields) is used in the expression
- Arguments passed to some elemental and transformational intrinsic procedures

Notes on Variables

- Variables that specify storage with allocate, except those of types noted in the previous section, will be unassigned-checked when \( -\text{CU} \) is selected.

- If the variables in a named COMMON block are to be unassigned-checked, \( -\text{CU} \) must be selected, and:
  - The COMMON block must be specified in one and only one BLOCK DATA program unit. Variables in the COMMON block that are not explicitly initialized will be subject to the unassigned check.
  - No variable of the COMMON block may be initialized outside the BLOCK DATA program unit.

- Variables in blank COMMON will be subject to the unassigned check if \( -\text{CU} \) is selected and the blank COMMON appears in the main program unit. In this case, although the Intel® Fortran Compiler permits blank COMMON to have different sizes in different program units, only the variables within the extent of blank COMMON indicated in the main program unit will be subject to the unassigned check.

Actual to Dummy Argument Correspondence, \( -\text{CV} \)

Specifying the compile-time option \( -\text{CV} \) causes checks to be carried out at runtime that actual arguments to subprograms correspond with the dummy arguments expected. Note
Both caller and called Fortran code must be compiled with -CV (or -C). No argument checking will be performed unless this condition is satisfied.

The amount of checking performed depends upon whether the procedure call was made via an implicit interface or an explicit interface. Irrespective of the type of interface used, however, the following checks verify that:

- the correct number of arguments are passed.
- the type and type kinds of the actual and dummy arguments correspond.
- subroutines have been called as subroutines and that functions have been declared with the correct type and type kind.
- dummy arrays are associated with either an array or an element of an array and not a scalar variable or constant.
- the declared length of a dummy character argument is not greater than the declared length of associated actual argument.
- the declared length of a character scalar function result is the same length as that declared by the caller.
- the actual and dummy arguments of derived type correspond to the number and types of the derived type components.
- actual arguments were not passed using the intrinsic procedures %REF and %VAL.

If an implicit interface call was made, then yet another check is made whether an interface block should have been used.

If an explicit interface block was used, then further checks are made in addition to those described (in the second bullet) above, to validate the interface block. These checks verify that:

- the OPTIONAL attribute of each dummy argument has been correctly specified by the caller.
- the POINTER attribute of each dummy argument has been correctly specified by the caller.
- the declared length of a dummy pointer of type character is the same as the declared length of the associated actual pointer of type character.
- the rank of an assumed-shape array or dummy pointer matches the rank of the associated actual argument.
- the rank of an array-valued function or pointer-valued function has been correctly specified by the caller.

- the declared length of a character array-valued function or a character pointer-valued function is the same length as that declared by the caller.

**Diagnostic Report, –d{n}**

The command option –d{n} generates the additional information required for a list of the current values of variables to be output when certain runtime errors occur. Diagnostic reports are generated by the following:

- input/output errors
- an invalid reference to a pointer or an allocatable array (if –CA option selected)
- subscripts out of bounds (if –CB option selected)
- an invalid array argument to an intrinsic procedure (if –CS option selected)
- use of unassigned variables (if –CU option selected)
- argument mismatch (if –CV option selected)
- invalid assigned labels
- a call to the abort routine
- certain mathematical errors reported by intrinsic procedures
- hardware detected errors

**The Level of Output**

The level of output is progressively controlled by n, as follows:

<table>
<thead>
<tr>
<th>n=0 (or n omitted)</th>
<th>Displays only the procedure name and the number of the line at which the failure occurred. This is the default value.</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=1</td>
<td>Reports scalar variables local to program active units.</td>
</tr>
<tr>
<td>n=2</td>
<td>Reports local and COMMON scalars.</td>
</tr>
<tr>
<td>n&gt;2</td>
<td>Reports the first n elements of local and COMMON arrays and all scalars.</td>
</tr>
</tbody>
</table>

The appropriate error message will be output on stderr, and (if selected) a postmortem report will be produced.

**Selecting a Postmortem Report**

Each scalar or array will be displayed on a separate line in a form appropriate to the type of the variable. Thus, for example, variables of type integer will be output as integer values, and variables of type complex will be output as complex values.
The postmortem report will not include those program units which are currently active, but which have not been compiled with the \texttt{-d\{n\}} option. If no active program unit has been compiled with the \texttt{-d\{n\}} option then no postmortem report will be produced.

\textbf{Note}
Using the \texttt{-d\{n\}} option for postmortem reports disables optimization.

\section*{Invoking a Postmortem Report}

A postmortem report may be invoked by any of the following:

- an error detected as a consequence of using the \texttt{-CA}, \texttt{-CB}, \texttt{-CS}, \texttt{-CU}, \texttt{-CV} or \texttt{-C} options
- a call on abort
- an allocation error
- an invalid assigned label
- an input-output error
- an error reported by a mathematical procedure
- a signal generated by a program error such as illegal instruction
- an error reported by an intrinsic procedure

\section*{Postmortem Report Conventions}

The following conventions are used in postmortem output:

- A variable \texttt{var} declared in a module \texttt{mod} appears as \texttt{mod/var}.
- A module procedure \texttt{proc} in module \texttt{mod} appears as \texttt{mod$proc}.
- The fields of a variable \texttt{var} of derived data type are preceded by a line of the form \texttt{var\%}.

\section*{Example}

In this example, the command line

\textit{prompt}>ifc  \texttt{-CB -CU -d4 sample.f}

is used to compile the program that follows. When the program is executed, the
postmortem report (follows the program) is output, since the subscript \( m \) to array \( \text{num} \) is out of bounds.

### The Program

```fortran
1 module arith
2 integer count
3 data count /0/
4
5 contains
6
7 subroutine add(k,p,m)
8 integer num(3),p
9
10 count = count+1
11 m = k+p
12 j = num(m)
13 return
14 end subroutine
15
16 end module arith
17
18 program dosums
19 use arith
20 type set
21 integer sum, product
22 end type set
23
24 type(set) ans
25
26 call add(9,6,ans%sum)
27
28 end program dosums
```

### The Postmortem Report

```
Run-Time Error 406: Array bounds exceeded
In Procedure: arith$add
Diagnostics Entered From Subroutine arith$add Line 12
j = Not Assigned
k = 9
m = 15
num = Not Assigned, Not Assigned, Not Assigned, Not Assigned
p = 6
Module arith
```
Compiler Information Messages

These messages are generated by the following Intel® Fortran Compiler options:

<table>
<thead>
<tr>
<th>Disabling the sign-on message</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-nologo</td>
<td>Disables the display of the compiler version (or sign-on) message.</td>
</tr>
<tr>
<td></td>
<td>When you sign-on, the compiler displays the following information:</td>
</tr>
<tr>
<td></td>
<td>ID: the unique identification number for this compiler.</td>
</tr>
<tr>
<td></td>
<td>x.y.z: the version of the compiler.</td>
</tr>
<tr>
<td></td>
<td>years: the years for which the software is copyrighted.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Printing the list and brief description of the compiler driver options</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-help</td>
<td>You can print a list and brief description of the most useful compiler driver options by specifying the -help option to the compiler. To print this list, use this command:</td>
</tr>
<tr>
<td>IA-32 compiler:</td>
<td>prompt&gt;ifc -help or prompt&gt;ifc -?</td>
</tr>
<tr>
<td>Itanium® compiler:</td>
<td>prompt&gt;efc -help or prompt&gt;efc -?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Showing compiler version and driver tool commands</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-V</td>
<td>Displays compiler version information.</td>
</tr>
<tr>
<td>-v</td>
<td>Shows driver tool commands and executes tools.</td>
</tr>
<tr>
<td>-dryrun</td>
<td>Shows driver tool commands, but does not execute tools.</td>
</tr>
</tbody>
</table>

Diagnostic Messages

Diagnostic messages provide syntactic and semantic information about your source text. Syntactic information can include, for example, syntax errors and use of non-ANSI Fortran. Semantic information includes, for example, unreachable code.
Diagnostic messages can be any of the following: command-line diagnostics, warning messages, error messages, or catastrophic error messages.

**Command-line Diagnostics**

These messages report improper command-line options or arguments. If the command line contains an unrecognized option, the compiler passes the option to the linker. If the linker still does not recognize the option, the linker produces the diagnostic message.

Command-line error messages appear on the standard error device in the form:

```
driver-name: message
```

where

<table>
<thead>
<tr>
<th>driver-name</th>
<th>The name of the compiler driver.</th>
</tr>
</thead>
<tbody>
<tr>
<td>message</td>
<td>Describes the error.</td>
</tr>
</tbody>
</table>

Command-line warning messages appear as follows:

```
driver-name: warning: message
```

**Language Diagnostics**

These messages describe diagnostics that are reported during the processing of the source file. These diagnostics have the following format:

```
filename(linenum): type nn: message
```

<table>
<thead>
<tr>
<th>filename</th>
<th>Indicates the name of the source file currently being processed. An extension to the filename indicates the type of the source file, as follows: .f, f90, .for indicate a Fortran file.</th>
</tr>
</thead>
<tbody>
<tr>
<td>linenum</td>
<td>Indicates the source line where the compiler detects the condition.</td>
</tr>
<tr>
<td>type</td>
<td>Indicates the severity of the diagnostic message: warning, error, or Fatal error.</td>
</tr>
<tr>
<td>nn</td>
<td>The number assigned to the error (or warning) message.</td>
</tr>
<tr>
<td>message</td>
<td>Describes the diagnostic.</td>
</tr>
</tbody>
</table>

The following is an example of a warning message:
tantst.f(3): warning 328: "local variable": Local variable "increment" never used.

The compiler can also display internal error messages on the standard error device. If your compilation produces any internal errors, contact your Intel representative. Internal error messages are in the form:

FATAL COMPILER ERROR: message

Warning Messages

These messages report valid but questionable use of the language being compiled. The compiler displays warnings by default. You can suppress warning messages by using the -W0 option. Warnings do not stop translation or linking. Warnings do not interfere with any output files. Some representative warning messages are:

constant truncated - precision too great
non-blank characters beyond column 72 ignored
Hollerith size exceeds that required by the context

Suppressing or Enabling Warning Messages

The warning messages report possible errors and use of non-standard features in the source file.

The following options suppress or enable warning messages.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-cerrs[-]</td>
<td>Causes error and warning messages to be generated in a terse format: &quot;file&quot;, line no : error message</td>
</tr>
<tr>
<td>-w</td>
<td>Suppresses all warning messages.</td>
</tr>
<tr>
<td>-w90, -w95</td>
<td>Suppresses warning messages about Fortran features which are deprecated or obsoleted in Fortran 95.</td>
</tr>
<tr>
<td>-W{n}</td>
<td>Suppresses or displays all warning messages generated by preprocessing and compilation. n=0: suppresses all warnings n=1: displays warning messages. -W1 is the default.</td>
</tr>
</tbody>
</table>
For example, the following command compiles `newprog.f` and displays compiler errors, but not warnings:

**IA-32 compiler:**

```
prompt> ifc -W0 newprog.f
```

**Itanium® compiler:**

```
prompt> efc -W0 newprog.f
```

### Comment Messages

These messages indicate valid but unadvisable use of the language being compiled. The compiler displays comments by default. You can suppress comment messages with:

| -cm | Suppresses all comment messages. |

Comment messages do not terminate translation or linking, they do not interfere with any output files either. Some examples of the comment messages are:

- Null CASE construct
- The use of a non-integer DO loop variable or expression
- Terminating a DO loop with a statement other than CONTINUE or ENDDO

### Error Messages

These messages report syntactic or semantic misuse of Fortran. The compiler always displays error messages. Errors suppress object code for the error containing the error and prevent linking, but they make it possible for the parsing to continue to scan for any other errors. Some representative error messages are:

- line exceeds 132 characters
- unbalanced parenthesis
- incomplete string
# Suppressing or Enabling Error Messages

The error conditions are reported in the various stages of the compilation and at different levels of detail as explained below. For various groups of error messages, see [Lists of Error Messages](#).

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-e90, -e95</td>
<td>Enables issuing of errors rather than warnings for features that are non-standard Fortran.</td>
</tr>
<tr>
<td>-q</td>
<td>Suppresses compiler output to standard error, stderr.</td>
</tr>
<tr>
<td>-d{n}</td>
<td>Generates extra information needed to produce a list of current variables in a diagnostic report. For more details on -d{n}, see <a href="#">Selecting a Postmortem Report, -d{n}</a>.</td>
</tr>
</tbody>
</table>

Diagnostic reports are generated by the following:

- input-output errors
- an invalid reference to a pointer or an allocatable array (if -CA option selected)
- subscripts out of bounds (if -CB option selected)
- an invalid array argument to an intrinsic procedure (if -CS option selected)
- use of unassigned variables (if -CU option selected)
- argument mismatch (if -CV option selected)
- invalid assigned labels
- a call to the abort routine
- certain mathematical errors reported by intrinsic procedures
- hardware detected errors:

## Fatal Errors

- 80, 81, 82
- Fatal errors are reported in the following places and with the following levels of detail:
- Fatal errors are reported in the following places and with the following levels of detail:
These messages indicate environmental problems. Fatal error conditions stop translation, assembly, and linking. If a fatal error ends compilation, the compiler displays a termination message on standard error output. Some representative fatal error messages are:

Disk is full, no space to write object file

Incorrect number of intrinsic arguments

Too many segments, object format cannot support this many segments
Mixing C and Fortran

This section discusses implementation-specific ways to call C procedures from a Fortran program.

**Naming Conventions**

By default, the Fortran compiler converts function and subprogram names to lower case, and adds a trailing underscore. The C compiler never performs case conversion. A C procedure called from a Fortran program must, therefore, be named using the appropriate case. For example, consider the following calls:

<table>
<thead>
<tr>
<th>Call</th>
<th>The C procedure must be named</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALL PROCNAME()</td>
<td>procname_.</td>
</tr>
<tr>
<td>x=fnname()</td>
<td>fnname_.</td>
</tr>
</tbody>
</table>

In the first call, any value returned by `procname` is ignored. In the second call to a function, `fnname` must return a value.

**Passing Arguments between Fortran and C Procedures**

By default, Fortran subprograms pass arguments by reference; that is, they pass a pointer to each actual argument rather than the value of the argument. C programs, however, pass arguments by value. Consider the following:

- When a Fortran program calls a C function, the C function's formal arguments must be declared as pointers to the appropriate data type.

- When a C program calls a Fortran subprogram, each actual argument must be specified explicitly as a pointer.

**Using Fortran Common Blocks from C**

When C code needs to use a common block declared in Fortran, an underscore (_) must be appended to its name, see below.

```
Fortran code
common /cblock/ a(100)
real a
```
Example

This example demonstrates defining a COMMON block in Fortran for Linux, and accessing the values from C.

C code

```c
struct acstruct {
    float a[100];
};
extern struct acstruct
cblock_;```

Fortran code

```fortran
COMMON /MYCOM/ A, B(100), I, C
REAL(4) A
REAL(8) B
INTEGER(4) I
COMPLEX(4) C
A = 1.0
B = 2.0D0
I = 4
C = (1.0,2.0)
CALL GETVAL()
END
```

C code

```c
typedef struct compl complex;
struct compl{
    float real;
    float imag;
};

extern struct {
    float a;
    double b[100];
    int i;
    complex c[10];
} mycom_;

void getval_(){
    printf("a = %f\n",mycom_.a);
    printf("b[0] = %f\n",mycom_.b[0]);
    printf("i = %d\n",mycom_.i);
    printf("c[1].real = %
```
Fortran and C Scalar Arguments

Table that follows shows a simple correspondence between most types of Fortran and C data.

### Fortran and C Language Declarations

<table>
<thead>
<tr>
<th>Fortran</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer*1 x</td>
<td>char x;</td>
</tr>
<tr>
<td>integer*2 x</td>
<td>short int x;</td>
</tr>
<tr>
<td>integer*4 x</td>
<td>long int x;</td>
</tr>
<tr>
<td>integer x</td>
<td>long int x;</td>
</tr>
<tr>
<td>integer*8 x</td>
<td>long long x; or _int64 x</td>
</tr>
<tr>
<td>logical*1 x</td>
<td>char x;</td>
</tr>
<tr>
<td>logical*2 x</td>
<td>short int x;</td>
</tr>
<tr>
<td>logical*4 x</td>
<td>long int x;</td>
</tr>
<tr>
<td>logical x</td>
<td>long int x;</td>
</tr>
<tr>
<td>logical*8 x</td>
<td>long long x; or _int64 x</td>
</tr>
<tr>
<td>real*4 x</td>
<td>float x;</td>
</tr>
<tr>
<td>real*8 x</td>
<td>double x;</td>
</tr>
<tr>
<td>real x</td>
<td>float x;</td>
</tr>
<tr>
<td>real*16</td>
<td>No equivalent</td>
</tr>
<tr>
<td>double precision x</td>
<td>double x;</td>
</tr>
<tr>
<td>complex x</td>
<td>struct {float real, imag;} x</td>
</tr>
<tr>
<td>complex*8 x</td>
<td>struct {float real, imag;} x</td>
</tr>
<tr>
<td>complex*16 x</td>
<td>struct {double dreal, dimag;} x</td>
</tr>
<tr>
<td>double complex x</td>
<td>struct {double dreal, dimag;} x</td>
</tr>
<tr>
<td>complex(KIND=16)x</td>
<td>No equivalent</td>
</tr>
<tr>
<td>character*6 x</td>
<td>char x[6];</td>
</tr>
</tbody>
</table>
Example below illustrates the correspondence shown in the table above: a simple Fortran call and its corresponding call to a C procedure. In this example the arguments to the C procedure are declared as pointers.

**Example of Passing Scalar Data Types from Fortran to C**

<table>
<thead>
<tr>
<th>Fortran Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer I</td>
</tr>
<tr>
<td>integer*2 J</td>
</tr>
<tr>
<td>real x</td>
</tr>
<tr>
<td>double precision d</td>
</tr>
<tr>
<td>logical l</td>
</tr>
<tr>
<td>call vexp( i, j, x, d, l )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C Called Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>void vexp_ ( int *i, short *j, float *x, double *d, int *l )</td>
</tr>
<tr>
<td>{</td>
</tr>
<tr>
<td>...program text...</td>
</tr>
<tr>
<td>}</td>
</tr>
</tbody>
</table>

*Note*
The character data or complex data do not have a simple correspondence to C types.

### Passing Scalar Arguments by Value

A Fortran program compiled with the Intel® Fortran Compiler can pass scalar arguments to a C function by value using the nonstandard built-in function `%VAL`. The following example shows the Fortran code for passing a scalar argument to C and the corresponding C code.

**Example of Passing Scalar Arguments from Fortran to C**

<table>
<thead>
<tr>
<th>Fortran Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer i</td>
</tr>
<tr>
<td>double precision f, result, argbyvalue</td>
</tr>
<tr>
<td>result= argbyvalue(%VAL(I),%VAL(F))</td>
</tr>
<tr>
<td>END</td>
</tr>
</tbody>
</table>
In this case, the pointers are not used in C. This method is often more convenient, particularly to call a C function that you cannot modify, but such programs are not always portable.

![Note]

Arrays, records, complex data, and character data cannot be passed by value.

Array Arguments

The table below shows the simple correspondence between the type of the Fortran actual argument and the type of the C procedure argument for arrays of types INTEGER, INTEGER*2, REAL, DOUBLE PRECISION, and LOGICAL.

![Note]

There is no simple correspondence between Fortran automatic, allocatable, adjustable, or assumed size arrays and C arrays. Each of these types of arrays requires a Fortran array descriptor, which is implementation-dependent.

Array Data Type

<table>
<thead>
<tr>
<th>Fortran Type</th>
<th>C Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer x( )</td>
<td>int x[ ];</td>
</tr>
<tr>
<td>integer*1 x( )</td>
<td>signed char x[ ];</td>
</tr>
<tr>
<td>integer*2 x( )</td>
<td>short x[ ];</td>
</tr>
<tr>
<td>integer*4 x( )</td>
<td>long int x[ ];</td>
</tr>
<tr>
<td>integer*8 x( )</td>
<td>long long x[ ]; or <em>int64</em></td>
</tr>
<tr>
<td>real*4 x( )</td>
<td>float x[ ];</td>
</tr>
<tr>
<td>real*8 x( )</td>
<td>double x[ ];</td>
</tr>
<tr>
<td>real x( )</td>
<td>float x[ ];</td>
</tr>
<tr>
<td>real*16 x( )</td>
<td>No equivalent</td>
</tr>
<tr>
<td>double precision x</td>
<td>double x[ ];</td>
</tr>
<tr>
<td>( )</td>
<td></td>
</tr>
<tr>
<td>logical*1 x( )</td>
<td>char x[ ];</td>
</tr>
<tr>
<td>logical*2 x( )</td>
<td>short int x[ ];</td>
</tr>
<tr>
<td>logical*4 x( )</td>
<td>long int x[ ];</td>
</tr>
<tr>
<td>logical x( )</td>
<td>int x[ ];</td>
</tr>
<tr>
<td>logical*8 x( )</td>
<td>long long x[ ]; or <em>int64</em> x</td>
</tr>
</tbody>
</table>
Be aware that array arguments in the C procedure do not need to be declared as pointers. Arrays are always passed as pointers.

When passing arrays between Fortran and C, be aware of the following semantic differences:

- Fortran organizes arrays in column-major order (the first subscript, or dimension, of a multiply-dimensioned array varies the fastest); C organizes arrays in row-major order (the last dimension varies the fastest).

- Fortran array indices start at 1 by default; C indices start at 0. Unless you declare the Fortran array with an explicit lower bound, the Fortran element $X(1)$ corresponds to the C element $x[0]$.

Example below shows the Fortran code for passing an array argument to C and the corresponding C code.

**Example of Array Arguments in Fortran and C**

<table>
<thead>
<tr>
<th>Fortran Code</th>
<th>Corresponding C Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>dimension i(100), x(150)</code></td>
<td><code>array (i, isize, x, xsize)</code></td>
</tr>
<tr>
<td><code>call array(i, 100, x, 150)</code></td>
<td><code>int isize, *xsize;</code></td>
</tr>
<tr>
<td></td>
<td><code>{</code></td>
</tr>
<tr>
<td></td>
<td><code>. . . program text. . .</code></td>
</tr>
<tr>
<td></td>
<td><code>}</code></td>
</tr>
</tbody>
</table>

**Character Types**
If you pass a character argument to a C procedure, the called procedure must be declared with an extra integer argument at the end of its argument list. This argument is the length of the character variable.

The C type corresponding to character is char. Example that follows shows Fortran code for passing a character type called charmac and the corresponding C procedure.

Example of Character Types Passed from Fortran to C

For the corresponding C procedure in the above example, n1 and n2 are the number of characters in c1 and c2, respectively. The added arguments, n1 and n2, are passed by value, not by reference. Since the string passed by Fortran is not null-terminated, the C procedure must use the length passed.

Null-Terminated CHARACTER Constants

As an extension, the Intel Fortran Compiler enables you to specify null-terminated character constants. You can pass a null-terminated character string to C by making the length of the character variable or array element one character longer than otherwise necessary, to provide for the null character. For example:

For the corresponding C procedure in the above example, n1 and n2 are the number of characters in c1 and c2, respectively. The added arguments, n1 and n2, are passed by value, not by reference. Since the string passed by Fortran is not null-terminated, the C procedure must use the length passed.

Null-Terminated CHARACTER Constants

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Complex Types

To pass a complex or double complex argument to a C procedure, declare the corresponding argument in the C procedure as either of the two following structures, depending on whether the actual argument is complex or double complex:

```c
struct { float real, imag; } *complex;
struct { double real, imag; } *dcomplex;
```

Example below shows Fortran code for passing a complex type called `compl` and the corresponding C procedure.

**Example of Complex Types Passed from Fortran to C**

<table>
<thead>
<tr>
<th><strong>Fortran Code</strong></th>
<th><strong>Corresponding C Procedure</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>double complex dc</td>
<td>compl ( dc, c )</td>
</tr>
<tr>
<td>complex c</td>
<td>*dc;</td>
</tr>
<tr>
<td>call compl ( dc, c)</td>
<td>struct { double real, imag; } *dc;</td>
</tr>
<tr>
<td></td>
<td>struct { float real, imag; } *c;</td>
</tr>
<tr>
<td></td>
<td>{ . . .program text. . . }</td>
</tr>
</tbody>
</table>

**Return Values**

A Fortran subroutine is a C function with a void return type. A C procedure called as a function must return a value whose type corresponds to the type the Fortran program...
expects (except for character, complex, and double complex data types). The table below shows this correspondence.

### Return Value Data Type

<table>
<thead>
<tr>
<th>Fortran Type</th>
<th>C Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>int;</td>
</tr>
<tr>
<td>integer*1</td>
<td>signed char;</td>
</tr>
<tr>
<td>integer*2</td>
<td>short;</td>
</tr>
<tr>
<td>integer*4</td>
<td>long int x;</td>
</tr>
<tr>
<td>integer*8 x</td>
<td>long long x; or _int64</td>
</tr>
<tr>
<td>logical</td>
<td>int;</td>
</tr>
<tr>
<td>logical*1</td>
<td>char;</td>
</tr>
<tr>
<td>logical*2</td>
<td>short;</td>
</tr>
<tr>
<td>logical*4x</td>
<td>long int x;</td>
</tr>
<tr>
<td>logical*8</td>
<td>long long x; or _int64</td>
</tr>
<tr>
<td>real</td>
<td>float;</td>
</tr>
<tr>
<td>real*r x</td>
<td>float x;</td>
</tr>
<tr>
<td>real*8 x</td>
<td>double x;</td>
</tr>
<tr>
<td>real*16</td>
<td>No equivalent</td>
</tr>
<tr>
<td>double precision</td>
<td>double;</td>
</tr>
</tbody>
</table>

Example below shows Fortran code for a return value function called `cfunct` and the corresponding C routine.

### Example of Returning Values from C to Fortran

<table>
<thead>
<tr>
<th><strong>Fortran code</strong></th>
<th><strong>Corresponding C Routine</strong></th>
</tr>
</thead>
</table>
| integer iret, cfunct
| iret = cfunct()   | int cfunct ()
|                   | {
|                   | ...program text...
|                   | return i;
|                   | }

### Returning Character Data Types

If a Fortran program expects a function to return data of type `character`, the Fortran compiler adds two additional arguments to the beginning of the called procedure's argument list:

- The first argument is a pointer to the location where the called procedure should store
the result.

- The second is the maximum number of characters that must be returned, padded with white spaces if necessary.

The called routine must copy its result through the address specified in the first argument. Example that follows shows the Fortran code for a return character function called makechars and corresponding C routine.

**Example of Returning Character Types from C to Fortran**

<table>
<thead>
<tr>
<th>Fortran code</th>
<th>Corresponding C Routine</th>
</tr>
</thead>
<tbody>
<tr>
<td>character*10 chars, makechars</td>
<td>void makechars_ ( result, length, x, y );</td>
</tr>
<tr>
<td>double precision x, y</td>
<td>char *result;</td>
</tr>
<tr>
<td>chars = makechars( x, y )</td>
<td>int length;</td>
</tr>
<tr>
<td></td>
<td>double *x, *y;</td>
</tr>
<tr>
<td></td>
<td>{</td>
</tr>
<tr>
<td></td>
<td>...program text, producing</td>
</tr>
<tr>
<td></td>
<td>returnvalue...</td>
</tr>
<tr>
<td></td>
<td>for (i = 0; i &lt; length; i++ )</td>
</tr>
<tr>
<td></td>
<td>{</td>
</tr>
<tr>
<td></td>
<td>result[i] = returnvalue[i];</td>
</tr>
<tr>
<td></td>
<td>}</td>
</tr>
<tr>
<td></td>
<td>}</td>
</tr>
</tbody>
</table>

In the above example, the following restrictions and behaviors apply:

- The function's length and result do not appear in the call statement; they are added by the compiler.

- The called routine must copy the result string into the location specified by result; it must not copy more than length characters.

- If fewer than length characters are returned, the return location should be padded on the right with blanks; Fortran does not use zeros to terminate strings.

- The called procedure is type void.

- You must use lowercase names for C routines or ATTRIBUTE directives and INTERFACE blocks to make the calls using uppercase.

**Returning Complex Type Data**
If a Fortran program expects a procedure to return a complex or double-complex value, the Fortran compiler adds an additional argument to the beginning of the called procedure argument list. This additional argument is a pointer to the location where the called procedure must store its result.

Example below shows the Fortran code for returning a complex data type procedure called \texttt{wbat} and the corresponding C routine.

\textbf{Example of Returning Complex Data Types from C to Fortran}

<table>
<thead>
<tr>
<th>\textbf{Fortran code}</th>
<th>\textbf{Corresponding C Routine}</th>
</tr>
</thead>
</table>
| \begin{verbatim}
complex bat, wbat
real x, y
bat = wbat ( x, y )
\end{verbatim} | \begin{verbatim}
struct \_mycomplex { float real, imag };
typedef struct \_mycomplex \_single\_complex;
void wbat\_ (\_single\_complex location,
float \*x, float \*y)
{
float realpart;
float imaginarypart;
... program text, producing realpart and
imaginarypart...
*location.real = realpart;
*location.imag = imaginarypart;
}
\end{verbatim} |

In the above example, the following restrictions and behaviors apply:

- The argument location does not appear in the Fortran call; it is added by the compiler.
- The C subroutine must copy the result's real and imaginary parts correctly into location.
- The called procedure is type \texttt{void}.

If the function returned a double complex value, the type \texttt{float} would be replaced by the type \texttt{double} in the definition of location in \texttt{wbat}.

\section*{Procedure Names}

C language procedures or external variables can conflict with Fortran routine names if they
use the same names in lower case with a trailing underscore. For example:

**Fortran Code**
subroutine myproc(a,b)
end

**C Code**
void myproc_( float *a, float *b){
    
}

The expressions above are equivalent, but conflicting routine declarations. Linked into the same executable, they would cause an error at link time.

Many routines in the Fortran runtime library use the naming convention of starting library routine names with an `f_` prefix. When mixing C and Fortran, it is the responsibility of the C program to avoid names that conflict with the Fortran runtime libraries.

Similarly, Fortran library procedures also include the practice of appending an underscore to prevent conflicts.

**Pointers**

In the Intel® Fortran Compiler implementation, pointers are represented in memory in the form shown in the table that follows.

**Pointer Representation in Intel Fortran Compiler**

<table>
<thead>
<tr>
<th>Pointer To:</th>
<th>Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>a numeric scalar</td>
<td>one word representing the address of its target</td>
</tr>
<tr>
<td>a derived type scalar</td>
<td>one word representing the address of its target</td>
</tr>
<tr>
<td>a character scalar</td>
<td>two words, the first word containing the address of its target and the second containing its defined length</td>
</tr>
<tr>
<td>an array</td>
<td>a data structure of variable size that describes the target array; Intel reserves the right to modify the form of this structure without notice</td>
</tr>
</tbody>
</table>

**Calling C Pointer-type Function from Fortran**

In Intel® Fortran, the result of a C pointer-type function is passed by reference as an additional, hidden argument. The function on the C side needs to emulate this as follows:
Calling C Pointer Function from Fortran

The function’s result (int *) is returned as a pointer to a pointer (int **), and the C function must be of type void (not int*). The hidden argument comes at the end of the argument list, if there are other arguments, and after the hidden lengths of any character arguments.

In addition to pointer-type functions, the same mechanism should be used for Fortran functions of user-defined type, since they are also returned by reference as a hidden argument. The same is true for functions returning a derived type (structure) or character if the function is character*(*)

Note
Calling conventions such as these are implementation-dependent and are not covered by any language standards. Code that is using them may not be portable.

Implicit Interface

An implicit interface call is a call on a procedure in which the caller has no explicit information on the form of the arguments expected by the procedure; all calls within a Fortran program are of this form. All arguments passed through an implicit interface, apart from label arguments, are passed by address.

Fortran Implicit Argument Passing by Address
Actual arguments of type `character` are passed as a character descriptor, which consists of two words, see [Character Types](#).

Label arguments (alternate returns) are handled differently: subroutines which include one or more alternate returns in the argument list are compiled as integer functions; these functions return an index into a computed `goto`; the caller executes these `gosub`s on return. For example:

```fortran
call validate(x,*10,*20,*30)
```

is equivalent to

```fortran
goto (10,20,30), validate(x)
```

## Explicit Interface

Fortran provides various mechanisms by which the declarations of the dummy arguments within the called procedure can be made available to the caller while it is constructing the actual argument list. An explicit interface call is one to the following:

- a module procedure
- an internal procedure
- an external procedure for which an interface block is provided

In this form of call the construction of the actual argument list is controlled by the declarations of the dummy arguments, rather than by the characteristics of the actual arguments. As in an implicit interface call, all arguments (apart from label arguments) are passed by address, but the form of the address is controlled by attributes of the associated dummy argument, see the table below.

### Fortran Explicit Argument Passing by Address

<table>
<thead>
<tr>
<th>Argument</th>
<th>Address Passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>scalar</td>
<td>the address of the scalar</td>
</tr>
<tr>
<td>array</td>
<td>the address of the first element of the array</td>
</tr>
<tr>
<td>scalar pointer</td>
<td>the address of its target</td>
</tr>
<tr>
<td>array pointer</td>
<td>the address of the first element of its target</td>
</tr>
<tr>
<td>procedure</td>
<td>the address associated with the external name</td>
</tr>
</tbody>
</table>
As in an implicit interface call, arguments of type `character` are passed as a character descriptor, described in [Character Types](#).

Intel reserves the right to alter or modify the form of the internal data used to pass assumed-shape arrays and pointers to arrays. It is therefore not recommended that interfaces using these forms of argument are to be compiled with other than Intel® Fortran Compiler.

The call on an explicit interface need not associate an actual argument with a dummy argument if the dummy argument has the `optional` attribute. An `optional` argument that is not present for a particular call to a routine has a placeholder value passed instead of its address. The place-holer value for optional arguments is always -1.

### Intrinsic Functions

The normal argument passing mechanisms described in the preceding sections may sometimes not be appropriate when calling a procedure written in C. The Intel® Fortran Compiler also provides the intrinsic functions `%REF` and `%VAL` which may be used to modify the normal argument passing mechanism. These intrinsics must not be used when calling a procedure compiled by the Intel Fortran Compiler. See [Additional Intrinsic Functions section](#).
Reference Information

Compiler Limits: Maximum Size and Number

The table below shows the size or number of each item that the Intel® Fortran Compiler can process. All capacities shown in the table are tested values; the actual number can be greater than the number shown.

<table>
<thead>
<tr>
<th>Item</th>
<th>Tested Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum nesting of interface blocks</td>
<td>10</td>
</tr>
<tr>
<td>Maximum nesting of input/output implied DOs</td>
<td>20</td>
</tr>
<tr>
<td>Maximum nesting of array constructor implied DOs</td>
<td>20</td>
</tr>
<tr>
<td>Maximum nesting of include files</td>
<td>10</td>
</tr>
<tr>
<td>Maximum length of a character constant</td>
<td>32767</td>
</tr>
<tr>
<td>Maximum Hollerith length</td>
<td>4096</td>
</tr>
<tr>
<td>Maximum number of digits in a numeric constant</td>
<td>1024</td>
</tr>
<tr>
<td>Maximum nesting of parenthesized formats</td>
<td>20</td>
</tr>
<tr>
<td>Maximum nesting of DO, IF or CASE constructs</td>
<td>100</td>
</tr>
<tr>
<td>Maximum number of arguments to MIN and MAX</td>
<td>255</td>
</tr>
<tr>
<td>Maximum number of parameters</td>
<td>256</td>
</tr>
<tr>
<td>Maximum number of continuation lines in fixed or free form</td>
<td>99</td>
</tr>
<tr>
<td>Maximum width field for a numeric edit descriptor</td>
<td>1024</td>
</tr>
</tbody>
</table>

Additional Intrinsic Functions

The Intel® Fortran Compiler provides a few additional generic functions, and adds specific names to standard generic functions (in particular, to accommodate DOUBLE COMPLEX arguments). Some specific names are synonyms to standard names.

⚠️ Note

Many intrinsics listed in this section are handled as library calls. Not all the functions that are listed in the sections that follow can be inlined.

Synonyms

The Intel® Fortran provides synonyms for standard Fortran intrinsic names. They are given in the right-hand columns.
Note that the Fortran standard intrinsic `TINY` and the Intel additional intrinsic `EPTINY` are not synonyms. `TINY` returns the smallest positive normalized value appropriate to the type of its argument, whereas `EPTINY` returns the smallest positive denormalized value.

**DCMPLX Function**

The `DCMPLX` function must satisfy the following conditions:

- If `x` is of type `DOUBLE COMPLEX`, then `DCMPLX(x)` is `x`.

- If `x` is of type `INTEGER`, `REAL`, or `DOUBLE PRECISION`, then `DCMPLX(x)` is `DBLE(x) + 0i`

- If `x1` and `x2` are of type `INTEGER`, `REAL` or `DOUBLE PRECISION`, then `DCMPLX(x1, x2)` is `DBLE(x1) + DBLE(x2) * i`

- If `DCMPLX` has two arguments, then they must be of the same type, which must be `INTEGER`, `REAL` or `DOUBLE PRECISION`.

- If `DCMPLX` has one argument, then it may be `INTEGER`, `REAL` or `DOUBLE PRECISION`, `COMPLEX` or `DOUBLE COMPLEX`.

**LOC Function**

The `LOC` function returns the address of a variable or of an external procedure.

**Intel® Fortran KIND Parameters**

Each intrinsic data type (`INTEGER`, `REAL`, `COMPLEX`, `LOGICAL` and `CHARACTER`) has a `KIND` parameter associated with it. The actual values which the `KIND` parameter for each intrinsic type can take are implementation-dependent. The Fortran standard specifies that these values must be `INTEGER`, that there must be at least two `REAL KINDs` and two `COMPLEX KINDs` (corresponding in each case to default `REAL` and `DOUBLE PRECISION`), and that there must be at least one `KIND` for each...
of the INTEGER, CHARACTER and LOGICAL data types.

**INTEGER KIND values**

KIND=1 1-byte INTEGER  
KIND=2 2-byte INTEGER  
KIND=4 4-byte INTEGER *default* KIND  
KIND=8 8-byte INTEGER

**REAL KIND values**

KIND=4 4-byte REAL *default* KIND  
KIND=8 8-byte REAL *equivalent to* DOUBLE PRECISION  
KIND=16 16-byte REAL

**COMPLEX KIND values**

KIND=4 4-byte REAL & imaginary parts *default* KIND  
KIND=8 8-byte REAL & imaginary parts *equivalent to* DOUBLE COMPLEX  
KIND=16 16-byte REAL and imaginary parts *equivalent to* COMPLEX*32

**LOGICAL KIND values**

KIND=1 1-byte LOGICAL  
KIND=2 2-byte LOGICAL  
KIND=4 4-byte LOGICAL *default* KIND  
KIND=8 8-byte LOGICAL

**CHARACTER KIND value**

KIND=1 1-byte CHARACTER *default* KIND

Except for COMPLEX, the KIND numbers match the size of the type in bytes. For COMPLEX the KIND number is the KIND number of the REAL or imaginary part.

An include file (*f90_kinds.f90*) providing symbolic definitions, for use when defining KIND type parameters, is included as part of the standard Intel® Fortran release.

**Argument and Result KIND Parameters**

The following extensions to standard Fortran are provided:

- References to the following intrinsic functions return INTEGER (KIND=2) results when compile-time option -I2 or -i2 is specified: INT, IDINT, NINT, IDNINT, IFIX, MAX1, MIN1.
The following specific intrinsic functions may be given arguments of type `INTEGER(KIND=2)`: `IABS`, `FLOAT`, `MAX0`, `AMAX0`, `MIN0`, `AMIN0`, `IDIM`, `ISIGN`.

References to the following intrinsic functions return `INTEGER(KIND=8)`: results when compile-time option `-i2` or `-i2` is specified: `INT`, `IDINT`, `NINT`, `IDNINT`, `IFIX`, `MAX1`, `MIN1`.

The following specific intrinsic functions may be given arguments of type `INTEGER(KIND=8)`: `IABS`, `FLOAT`, `MAX0`, `AMAX0`, `MIN0`, `AMIN0`, `IDIM`, `ISIGN`.

References to the following specific intrinsic functions return `REAL(KIND=8)` results when compile-time option `-r8` is specified: `ALOG`, `ALOG10`, `AMAX1`, `AMIN1`, `AMOD`, `MAX1`, `MIN1`, `SNGL`, `REAL`.

References to the following specific intrinsic functions return results of type `COMPLEX(KIND=8)`, that is the real and imaginary parts are each of 8 bytes, when compile-time option `-r8` is specified: `CABS`, `CCOS`, `CEXP`, `CLOG`, `CSIN`, `CSQRT`, `CMPLX`.

### %REF and %VAL Intrinsic Functions

Intel® Fortran provides two additional intrinsic functions, `%REF` and `%VAL`, that can be used to specify how actual arguments are to be passed in a procedure call. They should not be used in references to other Fortran procedures, but may be required when referencing a procedure written in another programming language such as C.

| %REF (X) | Specifies that the actual argument X is to be passed as a reference to its value. This is how Intel Fortran normally passes arguments except those of type character. For each character value that is passed as an actual argument, Intel Fortran normally passes both the address of the argument and its length (with the length being appended on to the end of the actual argument list as a hidden argument. Passing a character argument using %REF does not pass the hidden length argument. |
| %VAL (X) | Specifies that the value of the actual argument X is to be passed to the called procedure rather than the traditional mechanism employed by Fortran where the address of the argument is passed. |

In general, %VAL passes its argument as a 32-bit, sign extended, value with the following exceptions: the argument cannot be an array, a procedure name, a multibyte Hollerith constant, or a character variable (unless its size is explicitly declared to be 1).

In addition, the following conditions apply:
• If the argument is a derived type scalar, then a copy of the argument is generated and the address of the copy is passed to the called procedure.

• An argument of complex type will be viewed as a derived-type containing two fields - a real part and an imaginary part, and is therefore passed in manner similar to derived-type scalars.

• An argument that is a double-precision real will be passed as a 64-bit floating-point value.

This behavior is compatible with the normal argument passing mechanism of the C programming language, and it is to pass a Fortran argument to a procedure written in C where %VAL is typically used.

The intrinsic procedures %REF and %VAL can only be used in each explicit interface block, or in the actual CALL statement or function reference as shown in the example that follows.

### Calling Intrinsic Procedures

```fortran
PROGRAM FOOBAR
  INTERFACE
    SUBROUTINE FRED(%VAL(X))
      INTEGER :: X
    END SUBROUTINE FRED
    FUNCTION FOO(%REF(IP))
      INTEGER :: IP, FOO
    END FUNCTION FOO
  END INTERFACE
  ...
  CALL FRED(I)  ! The value of I is passed to FRED
  J = FOO(I)    ! I passed to FOO by reference,
               ! FOO receives a reference to
               ! the value of I.
END PROGRAM
```

Alternatively:

```fortran
PROGRAM FOOBAR
  INTEGER :: FOO
  EXTERNAL FOO, FRED
  CALL fred(%VAL(I))
  J = FOO(%REF(I))
END PROGRAM
```
List of Additional Intrinsic Functions

To understand the tabular list of additional intrinsic functions that follows after these notes, take into consideration the following:

- Specific names are only included in the Additional Intrinsic Functions table if they are not part of standard Fortran.

- An intrinsic that takes an integer argument accepts either INTEGER(KIND=2) or INTEGER(KIND=4) or INTEGER(KIND=8).

- The abbreviation "double" stands for DOUBLE PRECISION.

- The abbreviation "dcomplex" stands for DOUBLE COMPLEX. Dcomplex type is an Intel® Fortran extension, as are all intrinsic functions taking dcomplex arguments or returning dcomplex results.

- If an intrinsic function has more than one argument, then they must all be of the same type.

- If a function name is used as an actual argument, then it must be a specific name, not a generic name.

- If a function name is used as a dummy argument, then it does not identify an intrinsic function in the subprogram, but has a data type according to the normal rules for variables and arrays.

### Additional Intrinsic Functions

<table>
<thead>
<tr>
<th>Intrinsic Function</th>
<th>Definition</th>
<th>Generic Name</th>
<th>Specific Name</th>
<th>No of Args</th>
<th>Type of Args</th>
<th>Type of Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type conversion</td>
<td>Conversion to double precision See Note 1</td>
<td>DREAL</td>
<td></td>
<td>1</td>
<td>real real<em>16 real</em>16</td>
<td>real real<em>16 real</em>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DREAL</td>
<td></td>
<td>1</td>
<td>integer<em>2 integer</em>4 integer*8</td>
<td>real<em>8 real</em>8 real*8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DREAL</td>
<td></td>
<td>1</td>
<td>integer<em>2 integer</em>4 integer<em>8 real</em>4</td>
<td>complex<em>16 complex</em>16 complex*16</td>
</tr>
<tr>
<td></td>
<td>Conversion of double complex See Note 2</td>
<td>DCMPLX</td>
<td>1 or 2</td>
<td>real*8</td>
<td>real*16</td>
<td>real*16</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Absolute value</td>
<td></td>
<td></td>
<td></td>
<td>ZABS</td>
<td>CDABS</td>
<td>TABS</td>
</tr>
<tr>
<td>Imaginary part of a complex argument</td>
<td></td>
<td></td>
<td></td>
<td>DIMAG</td>
<td>CDIMAG</td>
<td>TIMAG</td>
</tr>
<tr>
<td>Conjugate of a complex argument</td>
<td></td>
<td></td>
<td></td>
<td>DCONJG</td>
<td>GTCONJ</td>
<td>DCONJ</td>
</tr>
<tr>
<td>Square root</td>
<td></td>
<td></td>
<td></td>
<td>ZSQRT</td>
<td>SQRT</td>
<td>TSQRT</td>
</tr>
<tr>
<td>Exponential</td>
<td></td>
<td></td>
<td></td>
<td>ZEXP</td>
<td>CDEX</td>
<td>TEXP</td>
</tr>
<tr>
<td>Natural Logarithm</td>
<td></td>
<td></td>
<td></td>
<td>ZLOG</td>
<td>CDLOG</td>
<td>DLOG</td>
</tr>
<tr>
<td>Bitwise Operation</td>
<td></td>
<td></td>
<td></td>
<td>AND</td>
<td>AND</td>
<td>2</td>
</tr>
<tr>
<td>See Note 1</td>
<td></td>
<td></td>
<td></td>
<td>OR</td>
<td>OR</td>
<td>2</td>
</tr>
<tr>
<td>Exclusive OR</td>
<td></td>
<td></td>
<td></td>
<td>XOR</td>
<td>XOR</td>
<td>2</td>
</tr>
<tr>
<td>Shift left: x1 logically shifted left x2 must be &gt; 0</td>
<td></td>
<td></td>
<td></td>
<td>LSHIFT</td>
<td>2</td>
<td>integer</td>
</tr>
<tr>
<td>Feature</td>
<td>Description</td>
<td>Environment Inquiries. See Note 1</td>
<td>Base of number systems</td>
<td>Number of Significant Bits</td>
<td>Minimum Exponent</td>
<td>Maximum Exponent</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------------------------</td>
<td>------------------------</td>
<td>---------------------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Shift right: x logically shifted right bits.</td>
<td>x2 must be &gt; 0</td>
<td>RSHIFT</td>
<td>2</td>
<td>integer</td>
<td>integer</td>
<td>integer</td>
</tr>
<tr>
<td>Environ-mental Inquiries. See Note 1</td>
<td></td>
<td>EPBASE</td>
<td>1</td>
<td>real double</td>
<td>integer</td>
<td>integer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EPPREC</td>
<td>1</td>
<td>real double</td>
<td>integer</td>
<td>integer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EPEMIN</td>
<td>1</td>
<td>real double</td>
<td>integer</td>
<td>integer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EPEMAX</td>
<td>1</td>
<td>real double</td>
<td>integer</td>
<td>integer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EPTINY</td>
<td>1</td>
<td>real double</td>
<td>real double</td>
<td>double</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EPHUGE</td>
<td>1</td>
<td>integer</td>
<td>real double</td>
<td>real double</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EPMRSP</td>
<td>1</td>
<td>real double</td>
<td>real double</td>
<td>real double</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LOC</td>
<td>1</td>
<td>any</td>
<td>integer</td>
<td>integer</td>
</tr>
</tbody>
</table>
### Key Files Summary for IA-32 Compiler

The following tables list and briefly describe files that are installed for use by the IA-32 version of the compiler.

#### /bin Files

<table>
<thead>
<tr>
<th>Sine</th>
<th>sin(x)</th>
<th>SIN SIND</th>
<th>ZSIN SIND DSIND QSIND</th>
<th>dcomplex real<em>16 double real</em>16 complex*32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosine</td>
<td>cos(x)</td>
<td>COS COSD</td>
<td>ZCOS CDCOS COSD DCOSD QCOSD</td>
<td>dcomplex dcomplex real double real<em>16 complex</em>32</td>
</tr>
<tr>
<td>Tangent</td>
<td>tan(x)</td>
<td>TAND</td>
<td>TAND DTAND QTAND</td>
<td>real double real<em>16 complex</em>32</td>
</tr>
<tr>
<td>Arcsine</td>
<td>arcsin(x)</td>
<td>ASIND</td>
<td>ASIND DASIND QASIND</td>
<td>real double real<em>16 complex</em>32</td>
</tr>
<tr>
<td>Arc-cosine</td>
<td></td>
<td>ACOSD</td>
<td>ACOSD QCOSD DACOSD QCACOSD</td>
<td>real complex<em>32 double real</em>16 complex*32</td>
</tr>
<tr>
<td>Arctangent</td>
<td>arctan(x)</td>
<td>ATAND</td>
<td>ATAND DATAND QATAND</td>
<td>real double real<em>16 complex</em>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATAN2D</td>
<td>ATAN2D DATAN2D XATAN2D QATAN2D</td>
<td>real double real<em>16 complex</em>32</td>
</tr>
<tr>
<td>File</td>
<td>Description</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f90com</td>
<td>Executable used by the compiler</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fpp</td>
<td>Fortran preprocessor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ifc</td>
<td>Intel® Fortran Compiler</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ifc.cfg</td>
<td>Configuration file for use from command line</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ifccem</td>
<td>FCE Manager Utility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ifcvars.csh</td>
<td>Environment variables header file</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ifcvars.sh</td>
<td>Batch file to set environment variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>profmerge</td>
<td>Utility used for Profile Guided Optimizations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>proforder</td>
<td>Utility used for Profile Guided Optimizations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>xiar</td>
<td>Tool used for final interprocedural compilation prior to archiving.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>xild</td>
<td>Tool used for Interprocedural Optimizations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

/lib Files

<table>
<thead>
<tr>
<th>File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>libbindf90.a</td>
<td>Library of Binder utilities</td>
</tr>
<tr>
<td>libcepcf90.a</td>
<td>Fortran I/O library to coexist with C</td>
</tr>
<tr>
<td>libcepcf90.so</td>
<td>Shared Fortran I/O library to coexist with C</td>
</tr>
<tr>
<td>lincprts.a</td>
<td>C++ standard language library</td>
</tr>
<tr>
<td>lincprts.so</td>
<td>Shared C++ standard language library</td>
</tr>
<tr>
<td>libcx.a</td>
<td>C++ language library indicating I/O data location</td>
</tr>
<tr>
<td>libcx.so</td>
<td>Shared C++ language library indicating I/O data location</td>
</tr>
<tr>
<td>libf90.a</td>
<td>Intel-specific Fortran runtime library</td>
</tr>
<tr>
<td>libf90.a</td>
<td>Shared Intel-specific Fortran runtime library</td>
</tr>
<tr>
<td>libguide.a</td>
<td>OpenMP* library</td>
</tr>
<tr>
<td>libguide.so</td>
<td>Shared OpenMP library</td>
</tr>
<tr>
<td>libiepcf90.a</td>
<td>Intel-specific Fortran runtime I/O library</td>
</tr>
<tr>
<td>libiepcf90.so</td>
<td>Shared Intel-specific Fortran runtime I/O library</td>
</tr>
<tr>
<td>libimf.a</td>
<td>Special purpose math library functions, including some transcendentals, built only for Linux</td>
</tr>
<tr>
<td>libimf.so</td>
<td>Shared special purpose math library functions, including some transcendentals, built only for Linux</td>
</tr>
<tr>
<td>libintrins.a</td>
<td>Intrinsic functions library</td>
</tr>
<tr>
<td>libintrins.so</td>
<td>Shared intrinsic functions library</td>
</tr>
</tbody>
</table>
The following tables list and briefly describe files that are installed for use by the Itanium® compiler version of the compiler.

### /bin Files

<table>
<thead>
<tr>
<th>File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>f90com</td>
<td>Executable used by the compiler</td>
</tr>
<tr>
<td>fpp</td>
<td>Fortran preprocessor</td>
</tr>
<tr>
<td>efc</td>
<td>Intel® Fortran Compiler</td>
</tr>
<tr>
<td>efc.cfg</td>
<td>Configuration file for use from command line</td>
</tr>
<tr>
<td>efccem</td>
<td>FCE Manager utility</td>
</tr>
<tr>
<td>efcvars.csh</td>
<td>Environment variables header file</td>
</tr>
<tr>
<td>efcvars.sh</td>
<td>Batch file to set environment variables</td>
</tr>
<tr>
<td>profmerge</td>
<td>Utility used for Profile Guided Optimizations</td>
</tr>
<tr>
<td>proforder</td>
<td>Utility used for Profile Guided Optimizations</td>
</tr>
<tr>
<td>xiar</td>
<td>Tool used for final interprocedural compilation prior to archiving.</td>
</tr>
<tr>
<td>xild</td>
<td>Tool used for Interprocedural Optimizations</td>
</tr>
</tbody>
</table>

### /lib Files

<table>
<thead>
<tr>
<th>File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>libasmutils.so</td>
<td>Library of Intel Itanium Assembler utilities</td>
</tr>
<tr>
<td>libcepcf90.a</td>
<td>Fortran I/O library to coexist with C</td>
</tr>
<tr>
<td>libcepcf90.so</td>
<td>Shared Fortran I/O library to coexist with C</td>
</tr>
<tr>
<td>libcprts.a</td>
<td>C++ standard language library</td>
</tr>
<tr>
<td>Library Name</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>libcprts.so</td>
<td>Shared C++ standard language library</td>
</tr>
<tr>
<td>libcxa.a</td>
<td>C++ language library indicating I/O data location</td>
</tr>
<tr>
<td>libcxa.so</td>
<td>Shared C++ language library indicating I/O data location</td>
</tr>
<tr>
<td>libdeceia.a</td>
<td>Assembler decoder library for IA-32 instructions on Itanium processor.</td>
</tr>
<tr>
<td>libdeceia.so</td>
<td>Shared assembler decoder library for IA-32 instructions on Itanium processor.</td>
</tr>
<tr>
<td>libdecem.a</td>
<td>Assembler decoder library for Itanium processor.</td>
</tr>
<tr>
<td>libdecem.so</td>
<td>Shared assembler decoder library for Itanium processor.</td>
</tr>
<tr>
<td>libdecem68.a</td>
<td>Assembler decoder library for Pentium® 4 processor.</td>
</tr>
<tr>
<td>libdecem68.so</td>
<td>Shared assembler decoder library for Pentium® 4 processor.</td>
</tr>
<tr>
<td>libdiseia.a</td>
<td>Disassembly library for IA-32 instructions on Itanium processor.</td>
</tr>
<tr>
<td>libdiseia.so</td>
<td>Shared disassembly library for IA-32 instructions on Itanium processor.</td>
</tr>
<tr>
<td>libdisem.a</td>
<td>Disassembly library for Itanium processor.</td>
</tr>
<tr>
<td>libdisem.so</td>
<td>Shared disassembly library for Itanium processor.</td>
</tr>
<tr>
<td>libdisp68.a</td>
<td>Disassembly library for Pentium 4 processor.</td>
</tr>
<tr>
<td>libdisp68.so</td>
<td>Shared disassembly library for Pentium 4 processor.</td>
</tr>
<tr>
<td>libenceia.a</td>
<td>Assembler encoder library for IA-32 instructions on Itanium processor.</td>
</tr>
<tr>
<td>libenceia.so</td>
<td>Shared assembler encoder library for IA-32 instructions on Itanium processor.</td>
</tr>
<tr>
<td>libencem.a</td>
<td>Assembler encoder library for Itanium processor.</td>
</tr>
<tr>
<td>libencem.so</td>
<td>Shared assembler encoder library for Itanium processor.</td>
</tr>
<tr>
<td>libencp68.a</td>
<td>Assembler encoder library for Pentium 4 processor.</td>
</tr>
<tr>
<td>libencp68.so</td>
<td>Shared assembler encoder library for Pentium 4 processor.</td>
</tr>
<tr>
<td>libf90.a</td>
<td>Intel-specific Fortran run-time library</td>
</tr>
<tr>
<td>libf90.so</td>
<td>Shared Intel-specific Fortran run-time library</td>
</tr>
<tr>
<td>libfpel.a</td>
<td>Floating point emulation assembly library.</td>
</tr>
<tr>
<td>libguide.a</td>
<td>OpenMP® static library</td>
</tr>
<tr>
<td>libguide.so</td>
<td>Shared OpenMP library</td>
</tr>
</tbody>
</table>
Error Message Lists

This section provides lists of error messages generated during compilation phases or reporting program error conditions. It includes the error messages for the following areas:

- runtime
- allocation
- input-output
- intrinsic procedures
- mathematical
- exceptions

## Runtime Errors (IA-32 Only)

These errors are caused by an invalid run-time operation. Following the message, a postmortem report is printed if any of the compile-time options `-C`, `-CA`, `-CB`, `-CS`, `-CU`, `-CV` or `-d{n}` was selected.

<table>
<thead>
<tr>
<th>Error</th>
<th>Option(s) Required</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td><code>-CU</code></td>
<td>Unassigned variable</td>
</tr>
<tr>
<td>404</td>
<td>none</td>
<td>Assigned label is not in specified list</td>
</tr>
<tr>
<td>405</td>
<td>none</td>
<td>Integer is not assigned with a format label</td>
</tr>
<tr>
<td>406</td>
<td><code>-CB</code></td>
<td>Array bounds exceeded</td>
</tr>
<tr>
<td>439</td>
<td>none</td>
<td>nth argument is not present</td>
</tr>
<tr>
<td>440</td>
<td>none</td>
<td>Inconsistent lengths in a pointer assignment</td>
</tr>
<tr>
<td>442</td>
<td>none</td>
<td>Inconsistent length for CHARACTER pointer function</td>
</tr>
<tr>
<td>447</td>
<td><code>-CS</code></td>
<td>Invalid DIM argument to LBOUND</td>
</tr>
<tr>
<td>448</td>
<td><code>-CS</code></td>
<td>Invalid DIM argument to UBOUND</td>
</tr>
<tr>
<td>449</td>
<td><code>-CS</code></td>
<td>Invalid DIM argument to SIZE</td>
</tr>
<tr>
<td>451</td>
<td>none</td>
<td>Procedure is a BLOCKDATA</td>
</tr>
<tr>
<td>454</td>
<td><code>-CS</code></td>
<td>Array shape mismatch</td>
</tr>
<tr>
<td>455</td>
<td><code>-CB</code></td>
<td>Array section bounds inconsistent with parent array</td>
</tr>
<tr>
<td>456</td>
<td><code>-CB</code></td>
<td>Invalid character substring ending position</td>
</tr>
<tr>
<td>457</td>
<td><code>-CB</code></td>
<td>Invalid character substring ending position</td>
</tr>
<tr>
<td>458</td>
<td>none</td>
<td>Object not allocated</td>
</tr>
<tr>
<td>459</td>
<td><code>-CA</code></td>
<td>Array not allocated</td>
</tr>
<tr>
<td>460</td>
<td><code>-CA</code></td>
<td>Pointer not allocated</td>
</tr>
<tr>
<td>461</td>
<td><code>-CA</code>, <code>-CU</code></td>
<td>Pointer is undefined</td>
</tr>
<tr>
<td>462</td>
<td><code>-CA</code></td>
<td>Assumed-shape array is not allocated</td>
</tr>
<tr>
<td>463</td>
<td><code>-CA</code></td>
<td>Assumed-shape array is undefined</td>
</tr>
<tr>
<td>464</td>
<td>none</td>
<td>Inconsistent lengths in a character array constructor</td>
</tr>
<tr>
<td></td>
<td><code>441 -CV</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>443 -CV</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>444 -CV</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>480 -CV</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>481−CV</td>
</tr>
<tr>
<td>-----</td>
<td>------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>441</td>
<td>−CV</td>
<td>Inconsistent length for CHARACTER pointer argument argument-name</td>
</tr>
<tr>
<td>443</td>
<td>−CV</td>
<td>Inconsistent length for CHARACTER argument</td>
</tr>
<tr>
<td>444</td>
<td>−CV</td>
<td>Inconsistent length for CHARACTER function</td>
</tr>
<tr>
<td>480</td>
<td>−CV</td>
<td>Too many arguments specified</td>
</tr>
<tr>
<td>481</td>
<td>−CV</td>
<td>Not enough arguments specified</td>
</tr>
<tr>
<td>*482</td>
<td>−CV</td>
<td>Incorrect interface block</td>
</tr>
<tr>
<td>*483</td>
<td>−CV</td>
<td>Interface block required for subprogram-name</td>
</tr>
<tr>
<td>*484</td>
<td>−CV</td>
<td>name is not a type-kind function-subroutine</td>
</tr>
<tr>
<td>*485</td>
<td>−CV</td>
<td>Argument type mismatch</td>
</tr>
<tr>
<td>*486</td>
<td>−CV</td>
<td>Array rank mismatch</td>
</tr>
</tbody>
</table>

*These errors are followed by additional information, as appropriate:

- nth dummy argument is not an actual-argument-type
- type1 actual argument passed to type2 dummy argument n
- type actual argument passed to cray-pointer dummy argument n
- Cray-pointer actual argument passed to type dummy argument n
- nth dummy argument is [not] a cray-pointer
- nth actual argument is not compatible with type RECORD
- name is [not] a pointer-valued function
- nth dummy argument is [not] a pointer
- name is [not] a dynamic CHARACTER function
- nth dummy argument is [not] optional
- nth dummy argument is [not] an assumed-shape array
- name is [not] an array-valued function
- nth dummy argument is an array but the actual argument is a scalar
- nth dummy argument is a scalar but the actual argument is an array
- The actual rank (x) of name does not match the declared rank (y)
• The data type of name does not match its declared type

• n\textsuperscript{th} dummy argument and the actual argument are different data types

• n\textsuperscript{th} actual argument passed to Fortran subprogram using \%VAL

• n\textsuperscript{th} actual argument passed to Fortran subprogram using \%REF

## Allocation Errors

The following errors can arise during allocation or deallocation of data space.

If the relevant \texttt{ALLOCATE} or \texttt{DEALLOCATE} includes a \texttt{STAT = } specifier, then an occurrence of any of the errors below will cause the \texttt{STAT} variable to become defined with the corresponding error number, instead of the error message being produced.

In the error messages, \texttt{vartype} is

<table>
<thead>
<tr>
<th>array</th>
<th>a pointer to an array, an allocatable array, or a temporary array</th>
</tr>
</thead>
<tbody>
<tr>
<td>character scalar</td>
<td>a pointer to a character scalar, an automatic character scalar, or a temporary character scalar</td>
</tr>
<tr>
<td>pointer</td>
<td>a pointer to a non-character scalar</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Error</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>491</td>
<td>\texttt{vartype} is already allocated.</td>
</tr>
<tr>
<td>492</td>
<td>\texttt{vartype} is not allocated.</td>
</tr>
<tr>
<td>493</td>
<td>\texttt{vartype} was not created by \texttt{ALLOCATE}.</td>
</tr>
<tr>
<td>494</td>
<td>Allocation of nnn bytes failed or Allocation of array with extent nnn failed or Allocation of array with element size nnn failed or Allocation of character scalar with element size nnn failed or Allocation of pointer with element size nnn failed.</td>
</tr>
<tr>
<td>495</td>
<td>Heap initialization failed.</td>
</tr>
</tbody>
</table>

## Input/Output Errors
The number and text of each input-output error message is given below, with the context in which it could occur and an explanation of the fault which has occurred. If the input-output statement includes an IOSTAT=STAT specifier, then an occurrence of any of the errors that follow will cause the STAT variable to become defined with the corresponding error number.

<table>
<thead>
<tr>
<th>Error</th>
<th>Message</th>
<th>Where Occurring</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>117</td>
<td>Unit not connected</td>
<td>OPEN</td>
<td>An attempt was made to read or write to a closed unit.</td>
</tr>
<tr>
<td>118</td>
<td>File already connected</td>
<td>OPEN</td>
<td>An attempt was made to OPEN a file on one unit while it was still connected to another.</td>
</tr>
<tr>
<td>119</td>
<td>ACCESS conflict</td>
<td>OPEN, Positional, READ, WRITE</td>
<td>When a file is to be connected to a unit to which it is already connected, then only the BLANK, DELIM, ERR, IOSTAT and PAD specifiers may be redefined. An attempt has been made to redefine the ACCESS specifier. This message is also used if an attempt is made to use a direct-access I/O statement on a unit which is connected for sequential I/O or a sequential I/O statement on a unit connected for direct access I/O.</td>
</tr>
<tr>
<td>120</td>
<td>RECL conflict</td>
<td>OPEN</td>
<td>When a file is to be connected to a unit to which it is already connected, then only the BLANK, DELIM, ERR, IOSTAT and PAD specifiers may be redefined. An attempt has been made to redefine the RECL specifier.</td>
</tr>
<tr>
<td>121</td>
<td>FORM conflict</td>
<td>OPEN</td>
<td>When a file is to be connected to a unit to which it is already connected, then only the BLANK, DELIM, ERR, IOSTAT and PAD specifiers may be redefined. An attempt has been made to redefine the FORM specifier.</td>
</tr>
<tr>
<td>122</td>
<td>STATUS conflict</td>
<td>OPEN</td>
<td>When a file is to be connected to a unit to which it is already connected, then only the BLANK, DELIM, ERR, IOSTAT and PAD specifier may be redefined. An attempt has been made to redefine the STATUS specifier.</td>
</tr>
<tr>
<td>123</td>
<td>Invalid STATUS</td>
<td>CLOSE</td>
<td>STATUS=DELETE has been specified in a CLOSE statement for a unit which has no write permissions; for example, the unit has been opened with the READONLY specifier.</td>
</tr>
<tr>
<td>125</td>
<td>Specifier not recognized</td>
<td>OPEN</td>
<td>A specifier value defined by the user has not been recognized.</td>
</tr>
<tr>
<td>Error Code</td>
<td>Description</td>
<td>Specifiers</td>
<td>Error Message</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------</td>
<td>------------</td>
<td>--------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>126</td>
<td>Specifiers inconsistent</td>
<td>OPEN</td>
<td>Within an OPEN statement one of the following invalid combinations of specifiers was defined by the user:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ACCESS=DIRECT was specified when STATUS=APPEND</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BLANK=FORMATTED was specified when FORM= UNFORMATTED</td>
</tr>
<tr>
<td>127</td>
<td>Invalid RECL value</td>
<td>OPEN,</td>
<td>The value of the RECL specifier was not a positive integer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DEFINE FILE</td>
<td></td>
</tr>
<tr>
<td>128</td>
<td>Invalid filename</td>
<td>INQUIRE</td>
<td>The name of the file in an Inquire by file statement is not a valid filename.</td>
</tr>
<tr>
<td>129</td>
<td>No filename specified</td>
<td>OPEN</td>
<td>In an OPEN statement, the STATUS specifier was not SCRATCH or UNKNOWN and no filename was defined.</td>
</tr>
<tr>
<td>130</td>
<td>Record length not specified</td>
<td>OPEN</td>
<td>The RECL specifier was not defined although ACCESS=DIRECT was specified.</td>
</tr>
<tr>
<td>131</td>
<td>An equals expected</td>
<td>Namelist</td>
<td>A variable name, array element or character substring reference in the input was not followed by an <code>=</code>.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>READ</td>
<td></td>
</tr>
<tr>
<td>132</td>
<td>Value separator missing</td>
<td>List-Directed READ, Namelist READ</td>
<td>A complex or literal constant in the input stream was not terminated by a delimiter (that is, by a space, a comma or a record boundary).</td>
</tr>
<tr>
<td>133</td>
<td>Value separator expected</td>
<td>Namelist</td>
<td>A subscript value in a character substring or array element reference in the input was not followed by a comma or close bracket.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>READ</td>
<td></td>
</tr>
<tr>
<td>134</td>
<td>Invalid scaling</td>
<td>WRITE with FORMAT</td>
<td>If d represents the decimal field of a format descriptor and k represents the current scale factor, then the ANSI Standard requires that the relationship -d&lt;k&lt;d+2 is true when an E or D format code is used with a WRITE statement. This requirement has been violated.</td>
</tr>
<tr>
<td>135</td>
<td>Invalid logical value</td>
<td>Formatted READ</td>
<td>A logical value in the input stream was syntactically incorrect.</td>
</tr>
<tr>
<td>136</td>
<td>Invalid character value</td>
<td>Namelist</td>
<td>A character constant does not begin with a quote character.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>READ</td>
<td></td>
</tr>
<tr>
<td>137</td>
<td>Value not recognized</td>
<td>List-Directed READ, Namelist READ</td>
<td>An item in the input stream was not recognized.</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
<td>Source</td>
<td>Error Message</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------</td>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>138</td>
<td>Invalid repetition value</td>
<td>List-Directed READ, Namelist READ</td>
<td>The value of a repetition factor found in the input stream is not a positive integer constant.</td>
</tr>
<tr>
<td>139</td>
<td>Illegal repetition factor</td>
<td>List-Directed READ, Namelist READ</td>
<td>A repetition factor in the input stream was immediately followed by another repetition factor.</td>
</tr>
<tr>
<td>140</td>
<td>Invalid integer</td>
<td>Formatted READ</td>
<td>The current input field contained a real number when an integer was expected.</td>
</tr>
<tr>
<td>141</td>
<td>Invalid real</td>
<td>Formatted READ</td>
<td>The current input field contained a real number which was syntactically incorrect.</td>
</tr>
<tr>
<td>143</td>
<td>Invalid complex constant</td>
<td>List-Directed READ, Namelist READ</td>
<td>The current input field contained a complex number which was syntactically incorrect.</td>
</tr>
<tr>
<td>144</td>
<td>Invalid subscript</td>
<td>Namelist READ</td>
<td>A subscript value in an array element reference in the input was not a valid integer.</td>
</tr>
<tr>
<td>145</td>
<td>Invalid substring</td>
<td>Namelist READ</td>
<td>A subscript value in a character substring reference was not a valid integer or was not positive.</td>
</tr>
<tr>
<td>146</td>
<td>Variable not in Namelist</td>
<td>Namelist READ</td>
<td>The data contained an assignment to a variable which is not in the NAMELIST list.</td>
</tr>
<tr>
<td>147</td>
<td>Variable not an array</td>
<td>Namelist READ</td>
<td>A variable name in the data was followed by an open bracket but the name is not an array or character variable.</td>
</tr>
<tr>
<td>148</td>
<td>Invalid character</td>
<td>Formatted READ</td>
<td>A character has been found in the current input stream which cannot syntactically be part of the entity being assembled.</td>
</tr>
<tr>
<td>149</td>
<td>Invalid Namelist input</td>
<td>Namelist READ</td>
<td>The first character of a record read by a Namelist READ statement was not a space.</td>
</tr>
<tr>
<td>150</td>
<td>Literal not terminated</td>
<td>List-Directed READ, Namelist READ</td>
<td>A literal constant in the input file was not terminated by a closing quote before the end of the file.</td>
</tr>
<tr>
<td>151</td>
<td>A variable name expected</td>
<td>Namelist READ</td>
<td>A list of array or array element values in the data contained too many values for the associated variable.</td>
</tr>
<tr>
<td>152</td>
<td>File does not exist</td>
<td>OPEN</td>
<td>An attempt has been made to open a file which does not exist with STATUS=OLD.</td>
</tr>
<tr>
<td>153</td>
<td>Input file ended</td>
<td>READ</td>
<td>All the data in the associated internal or external file has been read.</td>
</tr>
<tr>
<td>Error Code</td>
<td>Error Description</td>
<td>I/O Statement</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------</td>
<td>---------------</td>
<td>-------------</td>
</tr>
<tr>
<td>154</td>
<td>Wrong length record</td>
<td>READ, WRITE</td>
<td>READ, WRITE</td>
</tr>
<tr>
<td>155</td>
<td>Incompatible format descriptor</td>
<td>READ/WRITE with FORMAT</td>
<td>READ/WRITE with FORMAT</td>
</tr>
<tr>
<td>156</td>
<td>READ after WRITE</td>
<td>READ</td>
<td>READ</td>
</tr>
<tr>
<td>158</td>
<td>Record number out of range</td>
<td>Direct Access READ/WRITE, FIND</td>
<td>Direct Access READ/WRITE, FIND</td>
</tr>
<tr>
<td>159</td>
<td>No format descriptor for data item</td>
<td>READ/WRITE with FORMAT</td>
<td>READ/WRITE with FORMAT</td>
</tr>
<tr>
<td>160</td>
<td>READ after Endfile</td>
<td>READ</td>
<td>READ</td>
</tr>
<tr>
<td>161</td>
<td>WRITE operation failed</td>
<td>WRITE</td>
<td>WRITE</td>
</tr>
<tr>
<td>162</td>
<td>No WRITE permission</td>
<td>WRITE</td>
<td>WRITE</td>
</tr>
<tr>
<td>163</td>
<td>Unit not defined or connected</td>
<td>FIND</td>
<td>FIND</td>
</tr>
<tr>
<td>164</td>
<td>Invalid channel number</td>
<td>Any I-O Operation</td>
<td>Any I-O Operation</td>
</tr>
<tr>
<td>166</td>
<td>Unit already connected</td>
<td>DEFINE FILE</td>
<td>DEFINE FILE</td>
</tr>
<tr>
<td>167</td>
<td>Unit already defined</td>
<td>DEFINE FILE, OPEN</td>
<td>DEFINE FILE, OPEN</td>
</tr>
<tr>
<td>168</td>
<td>File already exists</td>
<td>OPEN</td>
<td>OPEN</td>
</tr>
<tr>
<td>169</td>
<td>Output file capacity exceeded</td>
<td>READ, WRITE</td>
<td>READ, WRITE</td>
</tr>
<tr>
<td>171</td>
<td>Invalid operation on file</td>
<td>Positional, READ, WRITE</td>
<td>Positional, READ, WRITE</td>
</tr>
<tr>
<td>Line</td>
<td>Type</td>
<td>Function</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>172</td>
<td>various</td>
<td>READ, WRITE</td>
<td>An unexpected error was returned by READ2 - the error text will be the NT* message associated with the failure.</td>
</tr>
<tr>
<td>173</td>
<td>various</td>
<td>READ, WRITE</td>
<td>An unexpected error was returned by WRITE - the error text will be the LINUX* message associated with the failure.</td>
</tr>
<tr>
<td>174</td>
<td>various</td>
<td>READ, WRITE</td>
<td>An unexpected error was returned by LSEEK - the error text will be the LINUX message associated with the failure.</td>
</tr>
<tr>
<td>175</td>
<td>various</td>
<td>OPEN, CLOSE</td>
<td>An unexpected error was returned by UNLINK - the error text will be the LINUX message associated with the failure.</td>
</tr>
<tr>
<td>176</td>
<td>various</td>
<td>OPEN, CLOSE</td>
<td>An unexpected error was returned by CLOSE - the error text will be the LINUX message associated with the failure.</td>
</tr>
<tr>
<td>177</td>
<td>various</td>
<td>OPEN</td>
<td>An unexpected error was returned by CREAT - the error text will be the LINUX message associated with the failure.</td>
</tr>
<tr>
<td>178</td>
<td>various</td>
<td>OPEN</td>
<td>An unexpected error was returned by OPEN - the error text will be the LINUX message associated with the failure.</td>
</tr>
<tr>
<td>181</td>
<td>Substring out of range</td>
<td>Namelist READ</td>
<td>A character substring reference in the input data lay beyond the bounds of the character variable.</td>
</tr>
<tr>
<td>182</td>
<td>Invalid variable name</td>
<td>Namelist READ</td>
<td>A name in the data was not a valid variable name.</td>
</tr>
<tr>
<td>185</td>
<td>Too many values</td>
<td>Namelist READ specified</td>
<td>A repetition factor (of the form r*c) exceeded the number of elements remaining unassigned in either an array or array element reference.</td>
</tr>
<tr>
<td>186</td>
<td>Not enough subscripts</td>
<td>Namelist READ specified</td>
<td>An array element reference contained fewer subscripts than are associated with the array.</td>
</tr>
<tr>
<td>187</td>
<td>Too many subscripts</td>
<td>Namelist READ specified</td>
<td>An array element reference contained more subscripts than are associated with the array.</td>
</tr>
<tr>
<td>188</td>
<td>Value out of range</td>
<td>Formatted READ</td>
<td>During numeric conversion from character to binary form a value in the input record was outside the range associated with the corresponding I-O item.</td>
</tr>
<tr>
<td>190</td>
<td>File not suitable</td>
<td>OPEN</td>
<td>A file which can only support sequential file operations has been opened for direct access I-O.</td>
</tr>
<tr>
<td>191</td>
<td>Workspace exhausted</td>
<td>OPEN</td>
<td>Workspace for internal tables has been exhausted.</td>
</tr>
<tr>
<td>Error Code</td>
<td>Description</td>
<td>Possible Statements</td>
<td>Error Message</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------</td>
<td>----------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>192</td>
<td>Record too long</td>
<td><strong>READ</strong></td>
<td>The length of the current record is greater than that permitted for the file as defined by the <strong>RECL=</strong> specifier in the <strong>OPEN</strong> statement.</td>
</tr>
<tr>
<td>193</td>
<td>Not connected for unformatted I-O</td>
<td><strong>Unformatted READ/WRITE</strong></td>
<td>An attempt has been made to access a formatted file with an unformatted I-O statement.</td>
</tr>
<tr>
<td>194</td>
<td>Not connected for formatted I-O</td>
<td><strong>Formatted READ/WRITE</strong></td>
<td>An attempt has been made to access an unformatted file with a formatted I-O statement.</td>
</tr>
<tr>
<td>195</td>
<td>Backspace not permitted</td>
<td><strong>BACKSPACE</strong></td>
<td>An attempt was made to <strong>BACKSPACE</strong> a file which contains records written by a list-directed output statement; this is prohibited by the ANSI Standard.</td>
</tr>
<tr>
<td>199</td>
<td>Field too large</td>
<td><strong>List-Directed READ, Namelist READ</strong></td>
<td>An item in the input stream was found to be more than 1024 characters long (this does not apply to literal constants).</td>
</tr>
<tr>
<td>203</td>
<td>POSITION conflict</td>
<td><strong>OPEN</strong></td>
<td>When a file is to be connected to a unit to which it is already connected, then only the <strong>BLANK</strong>, <strong>DELM</strong>, <strong>ERR</strong>, <strong>IOSTAT</strong> and <strong>PAD</strong> specifiers may be redefined. An attempt has been made to redefine the <strong>POSITION</strong> specifier.</td>
</tr>
<tr>
<td>204</td>
<td>ACTION conflict</td>
<td><strong>OPEN</strong></td>
<td>When a file is to be connected to a unit to which it is already connected, then only the <strong>BLANK</strong>, <strong>DELM</strong>, <strong>ERR</strong>, <strong>IOSTAT</strong> and <strong>PAD</strong> specifiers may be redefined. An attempt has been made to redefine the <strong>ACTION</strong> specifier.</td>
</tr>
<tr>
<td>205</td>
<td>No read permission</td>
<td><strong>READ</strong></td>
<td>An attempt has been made to <strong>READ</strong> from a unit which was <strong>OPENed</strong> with <strong>ACTION=&quot;WRITE&quot;</strong>.</td>
</tr>
<tr>
<td>206</td>
<td>Zero stride invalid</td>
<td><strong>Namelist READ</strong></td>
<td>An array subsection reference cannot have a stride of zero.</td>
</tr>
<tr>
<td>208</td>
<td>Incorrect array triplet syntax</td>
<td><strong>Namelist READ</strong></td>
<td>An array subsection triplet has been input incorrectly.</td>
</tr>
<tr>
<td>209</td>
<td>Name not a derived type</td>
<td><strong>Namelist READ</strong></td>
<td>A name in the data which is not a derived type has been followed by a <code>%</code>.</td>
</tr>
<tr>
<td>210</td>
<td>Invalid component name</td>
<td><strong>Namelist READ</strong></td>
<td>A derived type reference has not been followed by an <code>=</code>.</td>
</tr>
</tbody>
</table>
Little-Big Endian Conversion Errors

<table>
<thead>
<tr>
<th>Error</th>
<th>Message</th>
<th>Where Occurring</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>215</td>
<td>Conversion of derived data types is disabled</td>
<td>READ/WRITE</td>
<td>Conversion of derived data types is disabled if READ/WRITE statement refers to derived data type. Fatal error.</td>
</tr>
<tr>
<td>216</td>
<td>!Internal Error! Unknown data size</td>
<td>READ/WRITE</td>
<td>Unknown data size. Fatal error. Contact Intel.</td>
</tr>
<tr>
<td>217</td>
<td>!Internal Error! Conversion buffer too small</td>
<td>READ/WRITE</td>
<td>Conversion buffer too small. Fatal error. Contact Intel.</td>
</tr>
</tbody>
</table>

Other Errors Reported by I/O statements

Errors 101-107 arise from faults in run-time formats:

<table>
<thead>
<tr>
<th>Error</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>Syntax error in format</td>
</tr>
<tr>
<td>102</td>
<td>Format is incomplete</td>
</tr>
<tr>
<td>103</td>
<td>A positive value is required here</td>
</tr>
<tr>
<td>104</td>
<td>Minimum number of digits exceeds width</td>
</tr>
<tr>
<td>105</td>
<td>Number of decimal places exceeds width</td>
</tr>
<tr>
<td>106</td>
<td>Format integer constants &gt; 32767 are not supported</td>
</tr>
<tr>
<td>107</td>
<td>Invalid H edit descriptor</td>
</tr>
</tbody>
</table>

Notes
- The I/O statements OPEN, CLOSE and INQUIRE are classified as Auxiliary I/O statements. The I/O statements REWIND, ENDFILE and BACKSPACE are classified as Positional I/O statements.

- The IOSTAT = variable is set to -1 if an end-of-file condition occurs, to -2 if an end-of-record condition occurs (in a non-advancing READ), to the error number if one of the listed errors occurs, and to 0 if no error occurs.

- Should no input/output specifier relating to the type of the occurring input/output error be given (END=, EOR=, ERR= or IOSTAT=, as appropriate), then the input/output error will terminate the user program. All units which are currently opened will be closed, and the appropriate error message will be output on Standard Error followed (if requested) by a postmortem report (see Runtime Diagnostics).

- The form of an input/output error message is presented in the table below.

<table>
<thead>
<tr>
<th>I/O Error nnn:</th>
<th>Text of message</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Procedure:</td>
<td>Procedure name</td>
</tr>
<tr>
<td>At Line:</td>
<td>Line number</td>
</tr>
<tr>
<td>Statement:</td>
<td>I/O statement type</td>
</tr>
<tr>
<td>Unit:</td>
<td>Unit identifier or Internal File</td>
</tr>
<tr>
<td>Connected To:</td>
<td>File name</td>
</tr>
<tr>
<td>Form:</td>
<td>Formatted, Unformatted or Print</td>
</tr>
<tr>
<td>Access:</td>
<td>Sequential or Direct</td>
</tr>
<tr>
<td>Nextrec:</td>
<td>Record number</td>
</tr>
<tr>
<td>Records Read:</td>
<td>Number of records input</td>
</tr>
<tr>
<td>Records Written:</td>
<td>Number of records output</td>
</tr>
<tr>
<td>Current I/O Buffer:</td>
<td>Snapshot of the current record with a pointer to the current position</td>
</tr>
</tbody>
</table>

**Note**

Only as much information as is available or pertinent will be displayed.

### Intrinsic Procedure Errors

The following error messages, which are unnumbered, are generated when incorrect arguments are specified to the Intel® Fortran Compiler intrinsic procedures, and option –CS was selected at compile-time. The messages are given in alphabetic order.

Each message is preceded by a line of the form:

ERROR calling the intrinsic subprogram name:
where \textit{name} is the name of the intrinsic procedure called. The term "integer" indicates integer format of an argument.

\section*{List of Intrinsic Errors}

Argument integer of the intrinsic function name has string length integer. It should have string length at least integer.

Argument integer of the intrinsic function name is a rank integer array. It should be a rank integer array.

Argument integer of the intrinsic function name is an array with integer elements. It should be an array with at least integer elements.

Argument \textit{name} has the value integer and argument \textit{name} has the value integer. Both arguments should have non-negative values and their sum should be less than or equal to integer.

Array argument \textit{name} has size integer. It should have size integer.

Array arguments \textit{name1} and \textit{name2} should have the same shape. The shape of argument \textit{name1} is: (integer, integer, ..., integer). The shape of argument \textit{name2} is: (integer, integer, ..., integer).

At least one of the array arguments should have rank = 2. The extent of the last dimension of \texttt{MATRIX\_A} is integer. The extent of the first dimension of \texttt{MATRIX\_B} is integer. These values should be equal.

The \texttt{DIM} parameter had a value of integer. Its value should be integer.

The \texttt{DIM} parameter had a value of integer. Its value should be at least integer and no larger than integer.

The \textit{name} array has shape: (integer, integer, ..., integer). The shape of \textit{name} should be: (integer, integer, ..., integer).

The \texttt{NCOPIES} argument has a value of integer. \texttt{NCOPIES} should be non-negative.

The \texttt{ORDER} argument should be a permutation of the integer1 to integer. The contents of the \texttt{ORDER} argument array is: (integer, integer, ..., integer).

The rank of the \texttt{RESULT} array should be equal to the size of the \texttt{SHAPE} array. The rank of the \texttt{RESULT} array is integer. The size of the \texttt{SHAPE} array is integer.
The \texttt{RESULT} array has shape: (integer, integer, ..., integer).
The shape of the \texttt{RESULT} array should be: (integer, integer, ..., integer).

The \texttt{RESULT} array has size \texttt{integer}. It should have size \texttt{integer}.

The \texttt{RESULT} character string has length \texttt{integer}. It should have length \texttt{integer}.

The \texttt{SHAPE} argument has size \texttt{integer}.
Its size should be at least \texttt{integer} and no larger than \texttt{integer}.

- The \texttt{SHAPE} argument should have only non-negative elements.
- The contents of the \texttt{SHAPE} array is: (integer, integer, ..., integer).
- The \texttt{SIZE} argument has a value \texttt{integer}. Its value should be non-negative.
- The size of the \texttt{SOURCE} array should be at least \texttt{integer}.
- The size of the \texttt{SOURCE} array is \texttt{integer}.

- When setting seeds with the intrinsic function name, the first seed must be at least \texttt{integer} and not more than \texttt{integer}, and the second seed must be at least \texttt{integer} and not more than \texttt{integer}.

\section*{Mathematical Errors}

This section lists the errors that can be reported as a consequence of using an intrinsic function or the exponentiation operator \texttt{**}.

If any of the errors below is reported, the user program will terminate. A postmortem report (see \url{Runtime Diagnostics}) will be output if the program was compiled with the option \texttt{-d \{n\}}. All input-output units which are open will be closed.

The number and text of mathematical errors are:

<table>
<thead>
<tr>
<th>Error</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Negative \texttt{DOUBLE PRECISION} value raised to a non-integer power</td>
</tr>
<tr>
<td>17</td>
<td>\texttt{DOUBLE PRECISION} zero raised to non-positive power</td>
</tr>
<tr>
<td>22</td>
<td>\texttt{REAL} zero raised to non-positive power</td>
</tr>
<tr>
<td>23</td>
<td>Negative \texttt{REAL} value raised to a non-integer power</td>
</tr>
<tr>
<td>24</td>
<td>\texttt{REAL} value raised to too large a \texttt{REAL} power</td>
</tr>
<tr>
<td>38</td>
<td>\texttt{INTEGER} raised to negative \texttt{INTEGER} power</td>
</tr>
<tr>
<td>39</td>
<td>\texttt{INTEGER} zero raised to non-positive power</td>
</tr>
<tr>
<td>40</td>
<td>\texttt{INTEGER} to \texttt{INTEGER} power overflows</td>
</tr>
</tbody>
</table>
Exception Messages

The following messages, which are unnumbered, are a selection of those which can be generated by exceptions (signals). They indicate that a hardware-detected or an asynchronous error has occurred. Note that you can obtain a postmortem report when an exception occurs by compiling with the \texttt{-d\{n\}} option.

The occurrence of an exception usually indicates that the Fortran program is faulty.

<table>
<thead>
<tr>
<th>Message</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>QUIT signal</strong></td>
<td>Program aborted by the user typing ^/ (ctrl + /)</td>
</tr>
<tr>
<td><strong>Illegal Instruction</strong></td>
<td>May be indicative of a bad call on a function that is defined to return a derived type result: either the sizes of the expected and actual results do not correspond, or the function has not been called as a derived type function.</td>
</tr>
<tr>
<td><strong>Alignment Error</strong></td>
<td>Access was attempted to a variable which is not aligned on an address boundary appropriate to its type; this could occur, for example, when a formal double-precision type variable is aligned on a single word boundary.</td>
</tr>
<tr>
<td><strong>Address Error</strong> <strong>Bus Error</strong></td>
<td>Usually caused by a wrong value being used as an address (check the associativity of all pointers).</td>
</tr>
</tbody>
</table>