

IBM XL Fortran for Linux, V15.1.6



# Getting Started with XL Fortran for Little Endian Distributions

*Version 15.1.6*



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**Note**

Before using this information and the product it supports, read the information in “Notices” on page 21.

**First edition**

This edition applies to IBM XL Fortran for Linux, V15.1.6 (Program 5765-J10; 5725-C75) and to all subsequent releases and modifications until otherwise indicated in new editions. Make sure you are using the correct edition for the level of the product.

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## About this document

This document contains overview and basic usage information for the IBM® XL Fortran for Linux, V15.1.6 compiler.

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## Who should read this document

This document is intended for Fortran developers who are looking for introductory overview and usage information for XL Fortran. It assumes that you have some familiarity with command-line compilers, basic knowledge of the Fortran programming language, and basic knowledge of operating system commands. Programmers new to XL Fortran can use this document to find information about the capabilities and features unique to XL Fortran.

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## How to use this document

Throughout this document, the `xlf` compiler invocation is used to describe the behavior of the compiler. You can, however, substitute other forms of the compiler invocation command if your particular environment requires it, and compiler option usage remains the same unless otherwise specified.

While this document covers general information such as configuring the compiler environment, and compiling and linking Fortran applications using the XL Fortran compiler, it does not include the following topics:

- Compiler installation: see the *XL Fortran Installation Guide*.
- Migration considerations and guide: see the *XL Fortran Migration Guide*.
- Compiler options: see the *XL Fortran Compiler Reference* for detailed information about the syntax and usage of compiler options.
- The Fortran programming language: see the *XL Fortran Language Reference* for information about the syntax, semantics, and IBM implementation of the Fortran programming language.
- Programming topics: see the *XL Fortran Optimization and Programming Guide* for detailed information about developing applications with XL Fortran, with a focus on program portability and optimization.
- CUDA Fortran support to exploit NVIDIA GPU: see the *Getting Started with CUDA Fortran programming using XL Fortran*.

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## How this document is organized

Chapter 1, “Introducing XL Fortran,” on page 1 contains information about the features of the XL Fortran compiler at a high level.

Chapter 2, “Setting up and customizing XL Fortran,” on page 9 describes how to set up and customize the compiler according to your own requirements.

Chapter 3, “Developing applications with XL Fortran,” on page 11 consists of repeating cycles of editing, compiling, linking, and running.

## Conventions

### Typographical conventions

The following table shows the typographical conventions used in the IBM XL Fortran for Linux, V15.1.6 information.

Table 1. *Typographical conventions*

Typeface	Indicates	Example
<b>lowercase bold</b>	Invocation commands, executable names, and compiler options.	The compiler provides basic invocation commands, <b>xlf</b> , along with several other compiler invocation commands to support various Fortran language levels and compilation environments.  The default file name for the executable program is <b>a.out</b> .
<i>italics</i>	Parameters or variables whose actual names or values are to be supplied by the user. Italics are also used to introduce new terms.	Make sure that you update the <i>size</i> parameter if you return more than the <i>size</i> requested.
<u>underlining</u>	The default setting of a parameter of a compiler option or directive.	nomaf   <u>maf</u>
monospace	Examples of program code, reference to program code, file names, path names, command strings, or user-defined names.	To compile and optimize myprogram.f, enter: xlf myprogram.f -O3.
<b>UPPERCASE bold</b>	Fortran programming keywords, statements, directives, and intrinsic procedures. Uppercase letters may also be used to indicate the minimum number of characters required to invoke a compiler option/suboption.	The <b>ASSERT</b> directive applies only to the <b>DO</b> loop immediately following the directive, and not to any nested <b>DO</b> loops.

### Qualifying elements (icons and bracket separators)

In descriptions of language elements or programming models, this information uses icons and marked bracket separators to delineate segments of text as follows:

Table 2. *Qualifying elements*













Icon	Bracket separator text	Meaning
 <b>F2008</b> 	Fortran 2008 begins / Fortran 2008 ends	The text describes an IBM XL Fortran implementation of the Fortran 2008 standard. <sup>1</sup>
 <b>F2003</b> 	Fortran 2003 begins / Fortran 2003 ends	The text describes an IBM XL Fortran implementation of the Fortran 2003 standard, and it applies to all later standards. <sup>1</sup>



Table 2. Qualifying elements (continued)

Icon	Bracket separator text	Meaning
 	TS 29113 begins / TS 29113 ends	The text describes an IBM XL Fortran implementation of Technical Specification 29113, referred to as TS 29113. <sup>1</sup>
 	IBM extension begins / IBM extension ends	The text describes a feature that is an IBM XL Fortran extension to the standard language specifications.
 	CUDA Fortran begins / CUDA Fortran ends	The text describes CUDA Fortran, the CUDA Fortran support provided by IBM XL Fortran, or both.
 	GPU begins / GPU ends	The text describes the information that is relevant to offloading computations to the NVIDIA GPUs.


**Note:**


1. If the information is marked with a Fortran language standard icon or bracket separators, it applies to this specific Fortran language standard and all later ones. Otherwise, it applies to all Fortran language standards.


## Syntax diagrams


Throughout this information, diagrams illustrate XL Fortran syntax. This section helps you to interpret and use those diagrams.



- Read the syntax diagrams from left to right, from top to bottom, following the path of the line.

The  symbol indicates the beginning of a command, directive, or statement.

The  symbol indicates that the command, directive, or statement syntax is continued on the next line.

The  symbol indicates that a command, directive, or statement is continued from the previous line.

The  symbol indicates the end of a command, directive, or statement.

Fragments, which are diagrams of syntactical units other than complete commands, directives, or statements, start with the  symbol and end with the  symbol.

IBM XL Fortran extensions are marked by a number in the syntax diagram with an explanatory note immediately following the diagram.

Program units, procedures, constructs, interface blocks and derived-type definitions consist of several individual statements. For such items, a box encloses the syntax representation, and individual syntax diagrams show the required order for the equivalent Fortran statements.

- Required items are shown on the horizontal line (the main path):

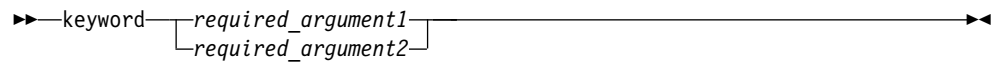
—keyword—required\_argument—

- Optional items are shown below the main path:



**Note:** Optional items (not in syntax diagrams) are enclosed by square brackets ([ and ]). For example, [UNIT=]u

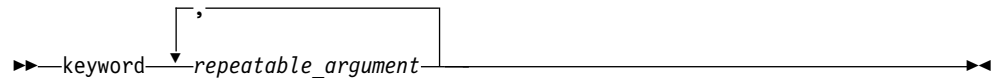
- If you can choose from two or more items, they are shown vertically, in a stack. If you *must* choose one of the items, one item of the stack is shown on the main path.



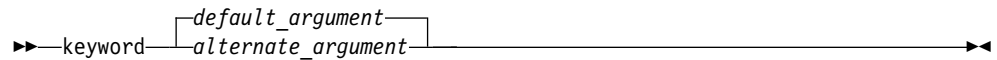
If choosing one of the items is optional, the entire stack is shown below the main path.



- An arrow returning to the left above the main line (a repeat arrow) indicates that you can make more than one choice from the stacked items or repeat an item. The separator character, if it is other than a blank, is also indicated:



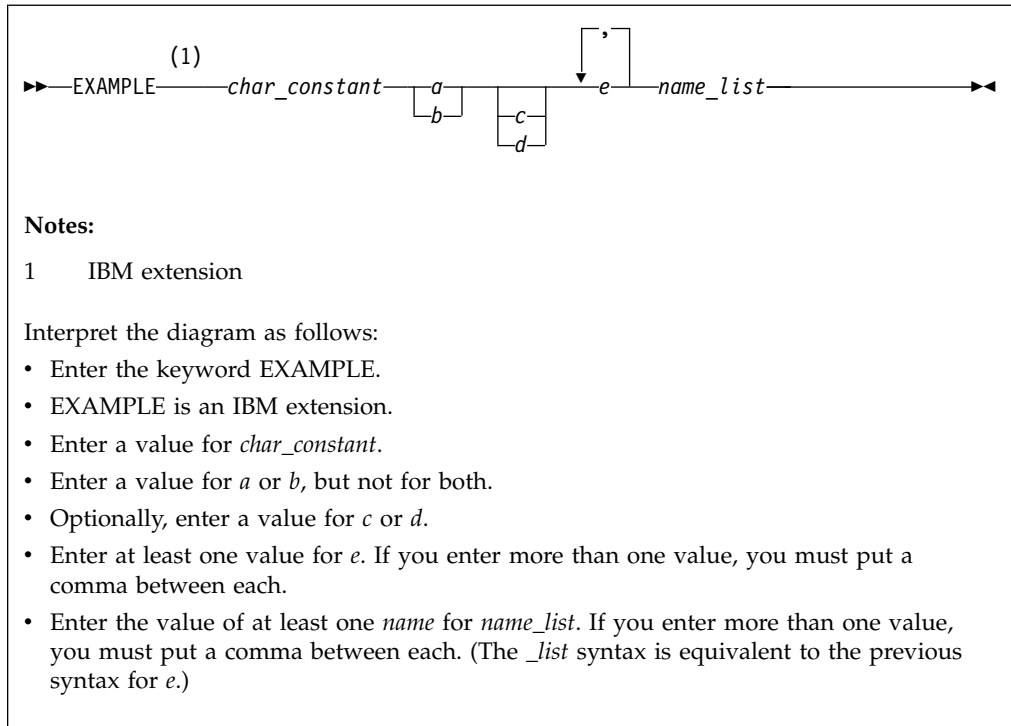
- The item that is the default is shown above the main path.



- Keywords are shown in nonitalic letters and should be entered exactly as shown.
- Variables are shown in italicized lowercase letters. They represent user-supplied names or values. If a variable or user-specified name ends in *\_list*, you can provide a list of these terms separated by commas.
- If punctuation marks, parentheses, arithmetic operators, or other such symbols are shown, you must enter them as part of the syntax.

### Sample syntax diagram

The following is an example of a syntax diagram with an interpretation:



## How to read syntax statements

Syntax statements are read from left to right:

- Individual required arguments are shown with no special notation.
- When you must make a choice between a set of alternatives, they are enclosed by { and } symbols.
- Optional arguments are enclosed by [ and ] symbols.
- When you can select from a group of choices, they are separated by | characters.
- Arguments that you can repeat are followed by ellipses (...).

## Example of a syntax statement

`EXAMPLE char_constant {a|b}[c|d]e[,e]... name_list{name_list}...`

The following list explains the syntax statement:

- Enter the keyword `EXAMPLE`.
- Enter a value for `char_constant`.
- Enter a value for `a` or `b`, but not for both.
- Optionally, enter a value for `c` or `d`.
- Enter at least one value for `e`. If you enter more than one value, you must put a comma between each.
- Optionally, enter the value of at least one `name` for `name_list`. If you enter more than one value, you must put a comma between each `name`.

**Note:** The same example is used in both the syntax-statement and syntax-diagram representations.

## Examples in this information

The examples in this information, except where otherwise noted, are coded in a simple style that does not try to conserve storage, check for errors, achieve fast performance, or demonstrate all possible methods to achieve a specific result.

The examples for installation information are labelled as either *Example* or *Basic example*. *Basic examples* are intended to document a procedure as it would be performed during a default installation; these need little or no modification.

## Notes on the terminology used

Some of the terminology in this information is shortened as follows:

- The term *free source form format* often appears as *free source form*.
- The term *fixed source form format* often appears as *fixed source form*.
- The term *XL Fortran* often appears as *XLF*.

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## Related information

The following sections provide related information for XL Fortran:

### Available help information

#### IBM XL Fortran information

XL Fortran provides product information in the following formats:

- Quick Start Guide

The Quick Start Guide (`quickstart.pdf`) is intended to get you started with IBM XL Fortran for Linux, V15.1.6. It is located by default in the XL Fortran directory and in the `\quickstart` directory of the installation DVD.

- README files

README files contain late-breaking information, including changes and corrections to the product information. README files are located by default in the XL Fortran directory, and in the root directory and subdirectories of the installation DVD.

- Installable man pages

Man pages are provided for the compiler invocations and all command-line utilities provided with the product. Instructions for installing and accessing the man pages are provided in the *IBM XL Fortran for Linux, V15.1.6 Installation Guide*.

- Online product documentation

The fully searchable HTML-based documentation is viewable in IBM Knowledge Center at [http://www.ibm.com/support/knowledgecenter/SSAT4T\\_15.1.6/com.ibm.compilers.linux.doc/welcome.html](http://www.ibm.com/support/knowledgecenter/SSAT4T_15.1.6/com.ibm.compilers.linux.doc/welcome.html).

- PDF documents

PDF documents are available on the web at [https://www.ibm.com/support/knowledgecenter/SSAT4T\\_15.1.6/com.ibm.compilers.linux.doc/download\\_pdf.html](https://www.ibm.com/support/knowledgecenter/SSAT4T_15.1.6/com.ibm.compilers.linux.doc/download_pdf.html).

The following files comprise the full set of XL Fortran product information.

**Note:** To ensure that you can access cross-reference links to other XL Fortran PDF documents, download and unzip the .zip file that contains all the product documentation files, or you can download each document into the same directory on your local machine.

*Table 3. XL Fortran PDF files*

Document title	PDF file name	Description
<i>What's New for IBM XL Fortran for Linux, V15.1.6, GC27-8037-00</i>	whats_new.pdf	Provides an executive overview of new functions in the IBM XL Fortran for Linux, V15.1.6 compiler, with new functions categorized according to user benefits.
<i>Getting Started with IBM XL Fortran for Linux, V15.1.6, SC27-6620-05</i>	getstart.pdf	Contains an introduction to XL Fortran, with information about setting up and configuring your environment, compiling and linking programs, and troubleshooting compilation errors.
<i>IBM XL Fortran for Linux, V15.1.6 Installation Guide, GC27-6580-05</i>	install.pdf	Contains information for installing XL Fortran and configuring your environment for basic compilation and program execution.
<i>IBM XL Fortran for Linux, V15.1.6 Migration Guide, GC27-8038-00</i>	migrate.pdf	Contains migration considerations for using XL Fortran to compile programs that were previously compiled on different platforms, by previous releases of XL Fortran, or by other compilers.
<i>IBM XL Fortran for Linux, V15.1.6 Compiler Reference, SC27-6610-05</i>	compiler.pdf	Contains information about the various compiler options and environment variables.
<i>IBM XL Fortran for Linux, V15.1.6 Language Reference, SC27-6590-05</i>	langref.pdf	Contains information about the Fortran programming language as supported by IBM, including language extensions for portability and conformance to nonproprietary standards, compiler directives and intrinsic procedures.
<i>IBM XL Fortran for Linux, V15.1.6 Optimization and Programming Guide, SC27-6600-05</i>	proguide.pdf	Contains information on advanced programming topics, such as application porting, interlanguage calls, floating-point operations, input/output, application optimization and parallelization, and the XL Fortran high-performance libraries.
<i>Getting Started with CUDA Fortran programming using IBM XL Fortran for Linux, V15.1.6, GI13-3562-02</i>	getstart_cudaf.pdf	Contains detailed information about the CUDA Fortran support that is provided in XL Fortran, including the compiler flow for CUDA Fortran programs, compilation commands, useful compiler options and macros, supported CUDA Fortran features, and limitations.

To read a PDF file, use Adobe Reader. If you do not have Adobe Reader, you can download it (subject to license terms) from the Adobe website at <http://www.adobe.com>.

More information related to XL Fortran, including IBM Redbooks® publications, white papers, and other articles, is available on the web at <http://www.ibm.com/support/docview.wss?uid=swg27036672>.

For more information about the compiler, see the XL compiler on Power® community at <http://ibm.biz/xl-power-compilers>.

### Other IBM information

- *ESSL product documentation* available at [http://www.ibm.com/support/knowledgecenter/SSFHY8/essl\\_welcome.html?lang=en](http://www.ibm.com/support/knowledgecenter/SSFHY8/essl_welcome.html?lang=en)

## Standards and specifications

XL Fortran is designed to support the following standards and specifications. You can refer to these standards and specifications for precise definitions of some of the features found in this information.

- *American National Standard Programming Language FORTRAN, ANSI X3.9-1978.*
- *American National Standard Programming Language Fortran 90, ANSI X3.198-1992.*
- *ANSI/IEEE Standard for Binary Floating-Point Arithmetic, ANSI/IEEE Std 754-1985.*
- *Federal (USA) Information Processing Standards Publication Fortran, FIPS PUB 69-1.*
- *Information technology - Programming languages - Fortran, ISO/IEC 1539-1:1991.* (This information uses its informal name, Fortran 90.)
- *Information technology - Programming languages - Fortran - Part 1: Base language, ISO/IEC 1539-1:1997.* (This information uses its informal name, Fortran 95.)
- *Information technology - Programming languages - Fortran - Part 1: Base language, ISO/IEC 1539-1:2004.* (This information uses its informal name, Fortran 2003.)
- *Information technology - Programming languages - Fortran - Part 1: Base language, ISO/IEC 1539-1:2010.* (This information uses its informal name, Fortran 2008. We currently provide partial support to this standard.)
- *Information technology - Further interoperability of Fortran with C, ISO/IEC TS 29113:2012.* (This information uses its informal name, Technical specification 29113, referred to as TS 29113. We currently provide partial support to this specification.)
- *Military Standard Fortran DOD Supplement to ANSI X3.9-1978, MIL-STD-1753* (United States of America, Department of Defense standard). Note that XL Fortran supports only those extensions documented in this standard that have also been subsequently incorporated into the Fortran 90 standard.
- *OpenMP Application Program Interface Version 3.1 (full support), OpenMP Application Program Interface Version 4.0 (partial support), and OpenMP Application Program Interface Version 4.5 (partial support),* available at <http://www.openmp.org>

### Other IBM information

- *ESSL product documentation* available at [http://www.ibm.com/support/knowledgecenter/SSFHY8/essl\\_welcome.html?lang=en](http://www.ibm.com/support/knowledgecenter/SSFHY8/essl_welcome.html?lang=en)

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## Technical support

Additional technical support is available from the XL Fortran Support page at [https://www.ibm.com/support/home/product/U128148Q26691I65/XL\\_Fortran\\_for\\_Linux](https://www.ibm.com/support/home/product/U128148Q26691I65/XL_Fortran_for_Linux). This page provides a portal with search capabilities to a large selection of Technotes and other support information.

If you cannot find what you need, you can send an email to [compinfo@cn.ibm.com](mailto:compinfo@cn.ibm.com).

For the latest information about XL Fortran, visit the product information site at <https://www.ibm.com/us-en/marketplace/xl-fortran-linux-compiler-power>.

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## How to send your comments

Your feedback is important in helping us to provide accurate and high-quality information. If you have any comments about this information or any other XL Fortran information, send your comments to [compinfo@cn.ibm.com](mailto:compinfo@cn.ibm.com).

Be sure to include the name of the manual, the part number of the manual, the version of XL Fortran, and, if applicable, the specific location of the text you are commenting on (for example, a page number or table number).





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## Chapter 1. Introducing XL Fortran

IBM XL Fortran for Linux, V15.1.6 is an advanced, high-performance compiler that can be used for developing complex, computationally intensive programs, including interlanguage calls with C programs.

This section contains information about the features of the XL Fortran compiler at a high level. It is intended for people who are evaluating the compiler and for new users who want to find out more about the product.

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### Commonality with other IBM compilers

IBM XL Fortran for Linux, V15.1.6 is part of a larger family of IBM C, C++, and Fortran compilers. XL Fortran, together with XL C/C++, comprises the family of XL compilers.

These compilers are derived from a common code base that shares compiler function and optimization technologies for a variety of platforms and programming languages. Programming environments include IBM AIX®, IBM Blue Gene®/Q, and selected Linux distributions. The common code base, along with compliance with international programming language standards, helps support consistent compiler performance and ease of code portability across multiple operating systems and hardware platforms.

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### Operating system and hardware support

This section describes the operating systems and hardware that IBM XL Fortran for Linux, V15.1.6 supports.

IBM XL Fortran for Linux, V15.1.6, for little endian distributions supports the following operating systems:

- Ubuntu Server 14.04
- Ubuntu Server 14.10
- Ubuntu Server 16.04
- SUSE Linux Enterprise Server 12 (SLES 12)
- SUSE Linux Enterprise Server 12 Service Pack 3 (SLES 12 SP3)
- Red Hat Enterprise Linux 7.3 (RHEL 7.3)
- Red Hat Enterprise Linux 7.4 (RHEL 7.4)
- Red Hat Enterprise Linux 7.4 for Power Little Endian (POWER9)
- Community Enterprise Operating System 7 (CentOS 7)

**Note:** To compile CUDA Fortran programs or programs that contain code to be offloaded to the NVIDIA GPUs, you must use either of the following operating systems:

- Ubuntu Server 16.04.3
- Red Hat Enterprise Linux 7.3 (RHEL 7.3) or above

See the README file and "Before installing XL Fortran" in the *XL Fortran Installation Guide* for a complete list of requirements.

The compiler, its libraries, and its generated object programs run on any IBM Power Systems™ server supported by your operating system distribution with the required software and disk space.



To exploit the various supported hardware configurations, the compiler provides options to tune the performance of applications according to the hardware type that runs the compiled applications.

---

## A highly configurable compiler

You can use a variety of compiler invocation commands and options to tailor the compiler to your unique compilation requirements.

### Compiler invocation commands

XL Fortran provides several commands to invoke the compiler, for example, `xlf`, `xlf90`, `xlf95`, `xlf2003`, `xlf2008`, and `xlcuf`  `xlcuf` . Compiler invocation commands are provided to support most standardized Fortran language levels and many popular language extensions.

The compiler also provides corresponding `_r` versions of most invocation commands, for example, `xlf_r`. The `_r` invocations instruct the compiler to link and bind object files to threadsafe components and libraries, and produce threadsafe object code for compiler-created data and procedures.

For more information about XL Fortran compiler invocation commands, see "Compiling XL Fortran programs" in the *XL Fortran Compiler Reference*.

### Compiler options

You can choose from a large selection of compiler options to control compiler behavior. You can benefit from using different options for the following tasks:

- Debugging your applications
- Optimizing and tuning application performance
- Selecting language levels and extensions for compatibility with nonstandard features and behaviors that are supported by other Fortran compilers
- Performing many other common tasks that would otherwise require changing the source code

You can specify compiler options through a combination of environment variables, compiler configuration files, command line options, and compiler directive statements embedded in your program source.

For more information about XL Fortran compiler options, see "Summary of compiler options" in the *XL Fortran Compiler Reference*.

### Custom compiler configuration files

The installation process creates a default compiler configuration file containing stanzas that define compiler option default settings.

If you frequently specify compiler option settings other than the default settings of XL Fortran, you can use makefiles to define your settings. Alternatively, you can create custom configuration files to define your own frequently used option settings.

For more information about using custom compiler configuration files, see “Using custom compiler configuration files” on page 9.

---

## Language standard compliance

This topic describes the Fortran programming language specifications that IBM XL Fortran for Linux, V15.1.6 supports.

- Partial support for ISO/IEC TS 29113:2012 (referred to as the Technical Specification for further interoperability with C or TS 29113)
- Partial support for ISO/IEC 1539-1:2010 (referred to as Fortran 2008 or F2008)
- ISO/IEC 1539-1:2004 (referred to as Fortran 2003 or F2003)
- ISO/IEC 1539-1:1997 (referred to as Fortran 95 or F95)
- ISO/IEC 1539-1:1991(E) and ANSI X3.198-1992 (referred to as Fortran 90 or F90)
- ANSI X3.9-1978 (referred to as FORTRAN 77)

In addition to the standard language levels, XL Fortran supports the following language extensions:

- Language extensions to support vector programming
- Common Fortran language extensions defined by other compiler vendors, in addition to those defined by IBM
- Industry extensions that are found in Fortran products from various compiler vendors
- Extensions specified in SAA Fortran

See "Standards and specifications" in the *XL Fortran Language Reference* for more information about Fortran language specifications and extensions.

## Source-code migration and conformance checking

XL Fortran provides compiler invocation commands that instruct the compiler to inspect your application for conformance to a specific language level and warn you if constructs and keywords do not conform to the specified language level.

You can also use the **-qlanglvl** compiler option to specify a language level. If the language elements in your program source do not conform to the specified language level, the compiler issues diagnostic messages. Additionally, you can name your source files with common filename extensions such as *.f77*, *.f90*, *.f95*, *.f03*, or *.f08*, and then use the generic compiler invocations such as **xlfc** or **xlfr** to automatically select the language level appropriate to the filename extension.

### Related information



**-qlanglvl**

---

## Utilities and commands

This topic introduces the main utilities and commands that are included with XL Fortran. It does not contain all compiler utilities and commands.

### Utilities

**install** The **install** utility installs and configures IBM XL Fortran for Linux, V15.1.6 for use on your system.

### **xlfc\_configure**

You can use the **xlfc\_configure** utility to facilitate the use of XL Fortran

with IBM Advance Toolchain. For details, see "Using IBM XL Fortran for Linux, V15.1.6 with the Advance Toolchain" in *XL Fortran Compiler Reference*.

## Commands

### **genhtml** command

The **genhtml** command converts an existing XML diagnostic report produced by the **-qlistfmt** option. You can choose to produce XML or HTML diagnostic reports by using the **-qlistfmt** option. The report can help you find optimization opportunities. For more information about how to use this command, see **genhtml** command in the *XL Fortran Compiler Reference*.

### Profile-directed feedback (PDF) related commands

#### **cleanpdf** command

The **cleanpdf** command removes all the PDF files or the specified PDF files from the directory to which profile-directed feedback data is written.

#### **mergepdf** command

The **mergepdf** command provides the ability to weigh the importance of two or more PDF records when combining them into a single record. The PDF records must be derived from the same executable.

#### **showpdf** command

The **showpdf** command displays the following types of profiling information for all the procedures executed in a PDF run (compilation under the **-qpdf1** option):

- Block-counter profiling
- Call-counter profiling
- Value profiling
- Cache-miss profiling, if you specified the **-qpdf1=level=2** option during the PDF1 step.

You can view the first two types of profiling information in either text or XML format. However, you can view value profiling and cache-miss profiling information only in XML format.

For more information, see **cleanpdf**, **mergepdf**, and **showpdf** in the *XL Fortran Compiler Reference*.

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## Advance Toolchain 9.0 support

IBM XL Fortran for Linux, V15.1.6 fully supports IBM Advance Toolchain 9.0, which is a set of open source development tools and runtime libraries. With IBM Advance Toolchain, you can take advantage of the latest POWER® hardware features on Linux, especially the tuned libraries.

For more information, see "Using IBM XL Fortran for Linux, V15.1.6 with Advance Toolchain" in the *XL Fortran Compiler Reference*.

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## Program optimization

XL Fortran provides several compiler options that can help you control the optimization and performance of your programs.

With these options, you can perform the following tasks:

- Select different levels of compiler optimizations.
- Control optimizations for loops, floating point, and other types of operations.
- Optimize a program for a particular class of machines or for a very specific machine configuration, depending on where the program will run.

Optimizing transformations can give your application better overall execution performance. XL Fortran provides a portfolio of optimizing transformations tailored to various supported hardware. These transformations offer the following benefits:

- Reducing the number of instructions executed for critical operations
- Restructuring generated object code to make optimal use of the Power Architecture<sup>®</sup> processors
- Improving the usage of the memory subsystem
- Exploiting the ability of the architecture to handle large amounts of shared memory parallelization

### Related information



Optimizing your applications



Optimization and tuning



Intrinsic procedures

---

## Shared memory parallelization

XL Fortran supports application development for multiprocessor system architectures.

You can use any of the following methods to develop your parallelized applications with XL Fortran:

- Directive-based shared memory parallelization (OpenMP, SMP)
- Instructing the compiler to automatically generate shared memory parallelization
- Message-passing-based shared or distributed memory parallelization (MPI)

The parallel programming facilities are based on the concept of threads. Parallel programming exploits the advantages of multiprocessor systems while maintaining a full binary compatibility with existing uniprocessor systems. This means that a multithreaded program that works on a uniprocessor system can take advantage of a multiprocessor system without recompiling.

For more information, see "Parallel programming with XL Fortran" in the *XL Fortran Optimization and Programming Guide*.

### OpenMP directives

OpenMP directives are a set of API-based commands supported by XL Fortran and many other IBM and non-IBM C, C++, and Fortran compilers.

You can use OpenMP directives to instruct the compiler how to parallelize a particular block of code. The existence of the directives in the source removes the need for the compiler to perform any dependence analysis on the parallel code. OpenMP directives require the presence of Pthread libraries to provide the necessary infrastructure for parallelization.

OpenMP directives address the following important issues of parallelizing an application:

1. Clauses and directives are available for scoping variables. Generally, variables should not be shared; that is, each thread should have its own copy of the variable.
2. Work sharing directives specify how the work contained in a parallel region of code should be distributed across the threads.
3. Directives are available to control synchronization between threads.

IBM XL Fortran for Linux, V15.1.6 includes the full support for the OpenMP API Version 3.1 specification and partial support for the OpenMP API Version 4.0 and OpenMP API Version 4.5 specifications for shared memory parallel programming. The OpenMP support in IBM XL Fortran for Linux, V15.1.6 falls into the following categories:

- Parallelization directives
- Routines for OpenMP
- Environment variables for parallel processing

#### **Related information**



Optimizing your applications



The OpenMP API specification for parallel programming

---

## **Diagnostic reports**

The compiler listings, XML reports, and HTML reports provide important information to help you develop and debug your applications more efficiently.

Listing information is organized into optional sections that you can include or omit. For more information about the applicable compiler options and the listing itself, see "Understanding XL Fortran compiler listings" in the *XL Fortran Compiler Reference*.

You can also obtain diagnostic information from the compiler in XML or HTML format. The XML and HTML reports provide information about optimizations that the compiler performed or could not perform. You can use this information to reduce programming effort when tuning applications, especially high-performance applications. The report is defined by an XML schema and is easily consumable by tools that you can create to read and analyze the results. For detailed information about this report and how to use it, see "Using reports to diagnose optimization opportunities" in the *XL Fortran Optimization and Programming Guide*.

---

## **Symbolic debugger support**

You can instruct XL Fortran to include debugging information in your compiled objects by using different levels of the **-g** or **-qdbg** compiler option.

The debugging information can be examined by **gdb** or any symbolic debugger that supports the DWARF debug format on Linux to help you debug your programs.

#### **Related information**



-g



-qdbg





---

## Chapter 2. Setting up and customizing XL Fortran

This section describes how to set up and customize the compiler according to your own requirements.

For complete prerequisite and installation information for XL Fortran, see "Before installing XL Fortran" in the *XL Fortran Installation Guide*.

---

### Using custom compiler configuration files

You can customize compiler settings and options by modifying the default configuration file or creating your own configuration file.

You have the following options to customize compiler settings:

- The XL Fortran compiler installation process creates a default compiler configuration file. You can directly modify this configuration file to add default options for specific needs. However, if you later apply updates to the compiler, you must reapply all of your modifications to the newly installed configuration file.
- You can create your own custom configuration file that either overrides or complements the default configuration file. The compiler can recognize and resolve compiler settings that you specify in your custom configuration files with compiler settings that are specified in the default configuration file. Compiler updates that might later affect settings in the default configuration file do not affect the settings in your custom configuration files.

#### Related information



Using custom compiler configuration files



---

## Chapter 3. Developing applications with XL Fortran

Fortran application development consists of repeating cycles of editing, compiling, linking, and running. By default, compiling and linking are combined into a single step.

### Notes:



- Before you use the compiler, ensure that XL Fortran is properly installed and configured. For more information, see the *XL Fortran Installation Guide*.
- To learn about writing Fortran programs, refer to the *XL Fortran Language Reference*.

---

### Compiler phases

A typical compiler invocation executes some or all of these activities in sequence. For link time optimizations, some activities are executed more than once during a compilation. As each compilation component runs, the results are sent to the next step in the sequence.

1. Preprocessing of source files
2. Compilation, which might consist of the following phases, depending on what compiler options are specified:
  - a. Front-end parsing and semantic analysis
  - b. Loop transformations
  - c. High-level optimization
  - d. Low-level optimization
  - e. Register allocation
  - f. Final assembly
3. Assembling the assembly (.s) files and the unpreprocessed assembler (.S) files after they are preprocessed
4. Object linking to create an executable application

 The compilation and linking processes of CUDA Fortran programs go through more phases than the typical process. For more information, see the *Getting Started with CUDA Fortran programming using XL Fortran*. 

To see the compiler step through these phases, specify the **-v** compiler option when you compile your application. To see the amount of time the compiler spends in each phase, specify **-qphsinfo**.

---

### Editing Fortran source files

To create Fortran source programs, you can use any text editor available on your system.

Source programs must be saved using a recognized file name suffix. See “XL Fortran input and output files” on page 15 for a list of suffixes recognized by XL Fortran.

For a Fortran source program to be a valid program, it must conform to the language definitions specified in the *XL Fortran Language Reference*.

---

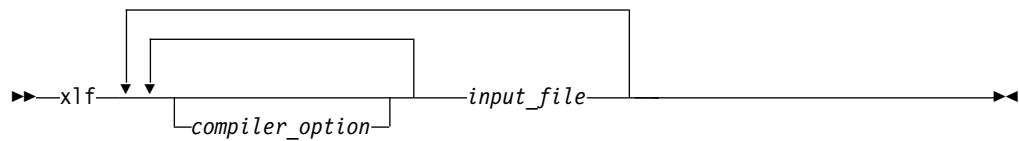
## Compiling with XL Fortran

XL Fortran is a command-line compiler. Invocation commands and options can be selected according to the needs of a particular Fortran application.



### Invoking the compiler

The compiler invocation commands perform all necessary steps to compile Fortran source files, assemble any .s and .S files, and link the object files and libraries into an executable program.

To compile a Fortran source program, use the following basic invocation syntax:







For most applications, compile with `xlf` or a threadsafe counterpart.

- If the file name extensions of your source files indicate a specific level of Fortran, such as .f08, .f03, .f95, .f90, or .f77, you can compile with `xlf` or the corresponding generic threadsafe invocations so that the compiler can automatically select the appropriate language-level defaults.
-  If the file name extensions are .cuf or .CUF, you can compile source files with `xlf_r` so that CUDA Fortran support is enabled automatically.  

- If you compile source files whose file name extensions are generic, such as .f or .F, with `xlf` or corresponding generic threadsafe invocations, the compilation conforms to FORTRAN 77.

For more information about threadsafe counterparts, see "Compiling XL Fortran programs" in the *XL Fortran Compiler Reference*.

### Invocation commands for different levels of Fortran

More invocation commands are available to meet specialized compilation needs, primarily to provide explicit compilation support for different levels and extensions of the Fortran language. These invocation commands do not consider the specific level of Fortran indicated by the source file name extensions, such as  .cuf  , .f08, .f03, .f95, .f90, or .f77.

 The `xlcuf` invocation command enables CUDA Fortran support for any Fortran source files. 

The invocation commands that relate to Fortran language levels are described as follows:

Table 4. Invocation commands and corresponding Fortran language standards

Language level	Invocation commands	Notes	
Fortran 2008	<ul style="list-style-type: none"><li>• f2008</li><li>• xlf2008</li></ul>	These compiler invocations accept Fortran 90 free source form by default. To use fixed source form with these invocations, you must specify the <b>-qfixed</b> option.	The Fortran 2008 language standard is partially supported in this release.
Fortran 2003	<ul style="list-style-type: none"><li>• f2003</li><li>• xlf2003</li></ul>		
Fortran 95	<ul style="list-style-type: none"><li>• f95</li><li>• xlf95</li></ul>		I/O formats are slightly different between these commands and the other commands. I/O formats for the Fortran 95 compiler invocations are also different from the I/O formats of Fortran 90 invocations. Switch to the Fortran 95 formats for data files whenever possible.
Fortran 90	<ul style="list-style-type: none"><li>• f90</li><li>• xlf90</li></ul>		
FORTRAN 77	<ul style="list-style-type: none"><li>• f77</li><li>• fort77</li></ul>	Where possible, these compiler invocations maintain compatibility with existing programs by using the same I/O formats as FORTRAN 77 and some implementation behaviors that are compatible with earlier versions of XL Fortran.  You might need to continue using these invocations for compatibility with existing makefiles and build environments. However, programs that are compiled with these invocations might not conform to the Fortran 2008, Fortran 2003, Fortran 95, or Fortran 90 language level standards.	

## Compiling with full compliance to language standards

By default, these invocation commands do not conform completely to the corresponding language standards. If you need full compliance, compile with the following compiler option settings and specify the following runtime options before you run the program, with a command similar to the following examples:

### Fortran 2008

#### Compiler options:

```
-qlanglvl=2008std -qnodirective -qnoescape -qextname
-qfloat=nomaf:nofold -qnoswapomp -qstrictieeeemod
```

#### Example of runtime options:

```
export XLF RTEOPTS="err_recovery=no:langlvl=2008std:
iostat_end=2003std:internal_nldelim=2003std"
```

### Fortran 2003

#### Compiler options:

```
-qlanglvl=2003std -qnodirective -qnoescape -qextname
-qfloat=nomaf:nofold -qnoswapomp -qstrictieeeemod
```

#### Example of runtime options:

```
export XLF RTEOPTS="err_recovery=no:langlvl=2003std:
iostat_end=2003std:internal_nldelim=2003std"
```

### Fortran 95

**Compiler options:**

```
-qlanglvl=95std -qnodirective -qnoescape -qextname
-qfloat=nomaf:nofold -qnoswapomp
```

**Example of runtime options:**

```
export XLF RTEOPTS="err_recovery=no:langlvl=95std"
```

**Fortran 90****Compiler options:**

```
-qlanglvl=90std -qnodirective -qnoescape -qextname
-qfloat=nomaf:nofold -qnoswapomp
```

**Example of runtime options:**

```
export XLF RTEOPTS="err_recovery=no:langlvl=90std"
```

The default settings are intended to provide the best combination of performance and usability, so change them only when full compliance is required. Some of the options that are mentioned in the preceding tables are only required for compliance in specific situations. For example, you must specify **-qextname** only when an external symbol, such as a common block or subprogram, is named **main**.

**The -qxlf2003 compiler option**

The **-qxlf2003** compiler option provides compatibility with XL Fortran V10.1 and the Fortran 2003 standard for certain aspects of the language.

When you compile with the Fortran 2003 or Fortran 2008 compiler invocations, the default setting is **-qxlf2003=polymorphic**. This setting instructs the compiler to allow polymorphic items such as the CLASS type specifier and SELECT TYPE construct in your Fortran application source.

For all other compiler invocations, the default is **-qxlf2003=nopolymorphic**.

**The -qxlf2008 compiler option**

You can use the **-qxlf2008** compiler option for the following purposes:

- To enable language features specific to the Fortran 2008 standard when you compile with compiler invocations that conform to earlier Fortran standards
- To disable language features specific to the Fortran 2008 standard when you compile with compiler invocations that conform to the Fortran 2008 standard

When you compile with the Fortran 2008 compiler invocations, the default setting is **-qxlf2008=checkpresence**. This setting instructs the compiler to check dummy argument presence according to the Fortran 2008 standard.

For all other compiler invocations, the default is **-qxlf2008=nocheckpresence**.

See "Compiling XL Fortran programs" in the *XL Fortran Compiler Reference* for more information about compiler invocation commands available to you.

**Specifying compiler options**

Compiler options perform a variety of functions, such as setting compiler characteristics, describing the object code to be produced, controlling the diagnostic messages emitted, and performing some preprocessor functions.

You can specify compiler options in one or any combination of the following ways:

- On the command line
- In your source code using directive statements
- In a makefile
- In the stanzas found in a compiler configuration file

You can also pass options to the linker, assembler, and preprocessor.

## Priority sequence of compiler options

Option conflicts and incompatibilities might occur when multiple compiler options are specified. To resolve these conflicts in a consistent manner, the compiler applies the following general priority sequence to most options:

1. Directive statements in your source file override command line settings.
2. Compiler option settings on the command line override configuration file settings.
3. Configuration file settings override default settings.

Generally, if the same compiler option is specified more than once on the command line when the compiler is invoked, the last option specified prevails.

**Note:** Some compiler options, such as the **-I** option, do not follow the priority sequence described above. The compiler searches any directories specified with **-I** in the `xlfcfg` file before it searches the directories specified with **-I** on the command line. The **-I** option is cumulative rather than preemptive. Other options with cumulative behavior are **-R** and **-l** (lowercase L).

### Related information



Specifying options on the command line

## XL Fortran input and output files

The topic describes the file types that are recognized by XL Fortran.

For detailed information about these and additional file types used by the compiler, see "Types of input files" in the *XL Fortran Compiler Reference* and "Types of output files" in the *XL Fortran Compiler Reference*.

Table 5. Input file types







Filename extension	Description
 <b>GPU</b> .bc 	LLVM IR bitcode libraries
.f, .F, .f77, .F77, .f90, .F90, .f95, .F95, .f03, .F03, .f08, .F08,  <b>CUDA Fortran</b> .cuf, .CUF  <b>CUDA Fortran</b>	Fortran source files
.mod	Module symbol files
.smod 	Submodule symbol files
.o	Object files
.s	Assembler files
.so	Shared object or library files
<b>Note:</b>  Fortran 2008	

Table 6. Output file types

Filename extension	Description
a.out	Default name for executable file created by the compiler
.mod	Module symbol files
.smod <b>1</b>	Submodule symbol files
.lst	Listing files
.o	Object files
.s	Assembler files
.so	Shared object or library files
<b>Note:</b> <b>1</b> Fortran 2008	

## Linking your compiled applications with XL Fortran

By default, you do not need to do anything special to link an XL Fortran program. The compiler invocation commands automatically call the linker to produce an executable output file.

For example, you can use `xlf` to compile `file1.f` and `file3.f` to produce object files `file1.o` and `file3.o`; after that, all object files, including `file2.o`, are submitted to the linker to produce one executable.

```
xlf file1.f file2.o file3.f
```

### Compiling and linking in separate steps

To produce object files that can be linked later, use the `-c` option.

```
xlf -c file1.f           # Produce one object file (file1.o)
xlf -c file2.f file3.f   # Or multiple object files (file2.o, file3.o)
xlf file1.o file2.o file3.o # Link object files with default libraries
```

## Dynamic and static linking

You can use XL Fortran to take advantage of the operating system facilities for both dynamic and static linking.

Dynamic linking means that the code for some external routines is located and loaded when the program is first run. When you compile a program that uses shared libraries, the shared libraries are dynamically linked to your program by default. Dynamically linked programs take up less disk space and less virtual memory if more than one program uses the routines in the shared libraries. During linking, they do not require any special precautions to avoid naming conflicts with library routines. They might perform better than statically linked programs if several programs use the same shared routines at the same time. By using dynamic linking, you can upgrade the routines in the shared libraries without relinking. This form of linking is the default and no additional options are needed.

Static linking means that the code for all routines called by your program becomes part of the executable file. Statically linked programs can be moved to run on systems without the XL Fortran runtime libraries. They might perform better than dynamically linked programs if they make many calls to library routines or call many small routines. They do require some precautions in choosing names for data objects and routines in the program if you want to avoid naming conflicts with library routines.



**Note:** Dynamically and statically linked programs might not work if you compile them on one level of the operating system and run them on a different level of the operating system.

---

## Running your compiled application

After a program is compiled and linked, you can run the generated executable file on the command line.

The default file name for the program executable file produced by the XL Fortran compiler is **a.out**. You can select a different name with the **-o** compiler option.

You should avoid giving your program executable file the same name as system or shell commands, such as `test` or `cp`, as you could accidentally execute the wrong command. If you do decide to name your program executable file with the same name as a system or shell command, you should execute your program by specifying the path name to the directory in which your executable file resides, such as `./test`.

To run a program, enter the name of the program executable file with runtime arguments on the command line.

### Canceling execution

To suspend a running program, press **Ctrl+Z** while the program is in the foreground. Use the **fg** command to resume running.

To cancel a running program, press **Ctrl+C** while the program is in the foreground.

### Setting runtime options

You can use environment variable settings to control certain runtime options and behaviors of applications created with the XL Fortran compiler. Some environment variables do not control actual runtime behavior, but they can have an impact on how your applications run.

For more information about environment variables and how they can affect your applications at run time, see the *XL Fortran Installation Guide*.

### Running compiled applications on other systems

If you want to run an application developed with the XL Fortran compiler on another system that does not have the compiler installed, you need to install a runtime environment on that system or link your application statically.

You can obtain the latest XL Fortran Runtime Environment images, together with licensing and usage information, from the XL Fortran for Linux support page.

---

## XL Fortran compiler diagnostic aids

XL Fortran issues diagnostic messages when it encounters problems compiling your application. You can use these messages and other information provided in compiler output listings to help identify and correct such problems.

For more information about listing, diagnostics, and related compiler options that can help you resolve problems with your application, see the following topics in the *XL Fortran Compiler Reference*:

- "Understanding XL Fortran compiler listings"
- "Error checking and debugging options"
- "Listings, messages, and compiler information options"

## Debugging compiled applications

You can use a symbolic debugger to debug applications compiled with XL Fortran.

At compile time, you can use the **-g** or **-q1 inedebug** option to instruct the XL Fortran compiler to include debugging information in compiled output. For **-g**, you can also use different levels to balance between debug capability and compiler optimization. For more information about the debugging options, see "Error checking and debugging" in the *XL Fortran Compiler Reference*.

You can then use **gdb** or any symbolic debugger that supports the DWARF debug format on Linux to step through and inspect the behavior of your compiled application.

Optimized applications pose special challenges when you debug your applications. For more information about debugging your optimized code, see "Debugging optimized code" in the *XL Fortran Optimization and Programming Guide*.

## Determining which level of XL Fortran is being used

To display the version and release level of XL Fortran that you are using, invoke the compiler with the **-qversion** compiler option.

For example, to obtain detailed version information, enter the following command:

```
xlf -qversion=verbose
```

---

## Appendix. Accessibility features for IBM XL Fortran for Linux

Accessibility features assist users who have a disability, such as restricted mobility or limited vision, to use information technology content successfully.

### Accessibility features

IBM XL Fortran for Linux uses the latest W3C Standard, WAI-ARIA 1.0 (<http://www.w3.org/TR/wai-aria/>), to ensure compliance to US Section 508 (<http://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-section-508-standards/section-508-standards>) and Web Content Accessibility Guidelines (WCAG) 2.0 (<http://www.w3.org/TR/WCAG20/>). To take advantage of accessibility features, use the latest release of your screen reader in combination with the latest web browser that is supported by this product.

The IBM XL Fortran for Linux online product documentation in IBM Knowledge Center is enabled for accessibility. The accessibility features of IBM Knowledge Center are described at IBM Knowledge Center help.

### Keyboard navigation

This product uses standard navigation keys.

### Interface information

You can use speech recognition software like a Text-to-speech (TTS) tool to view the output generated by the compiler.

The IBM XL Fortran for Linux online product documentation is available in IBM Knowledge Center, which is viewable from a standard web browser.

PDF files have limited accessibility support. With PDF documentation, you can use optional font enlargement, high-contrast display settings, and can navigate by keyboard alone.

To enable your screen reader to accurately read syntax diagrams, source code examples, and text that contains the period or comma PICTURE symbols, you must set the screen reader to speak all punctuation.

### Related accessibility information

To learn the accessibility features of the operation systems that are supported by IBM XL Fortran for Linux, see the following information:

- Ubuntu (<https://help.ubuntu.com/community/Accessibility>)
- SUSE Linux Enterprise Server (<https://www.suse.com>)
- Red Hat Enterprise Linux (<http://www.redhat.com>)
- Community Enterprise Operating System (<https://www.centos.org/>)

In addition to standard IBM help desk and support websites, IBM has established a TTY telephone service for use by deaf or hard of hearing customers to access sales and support services:

TTY service  
800-IBM-3383 (800-426-3383)  
(within North America)

### **IBM and accessibility**

For more information about the commitment that IBM has to accessibility, see IBM Accessibility ([www.ibm.com/able](http://www.ibm.com/able)).

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## Notices

Programming interfaces: Intended programming interfaces allow the customer to write programs to obtain the services of IBM XL Fortran for Linux.

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