# Get started with Arm Performance Libraries in Arm Compiler for Linux

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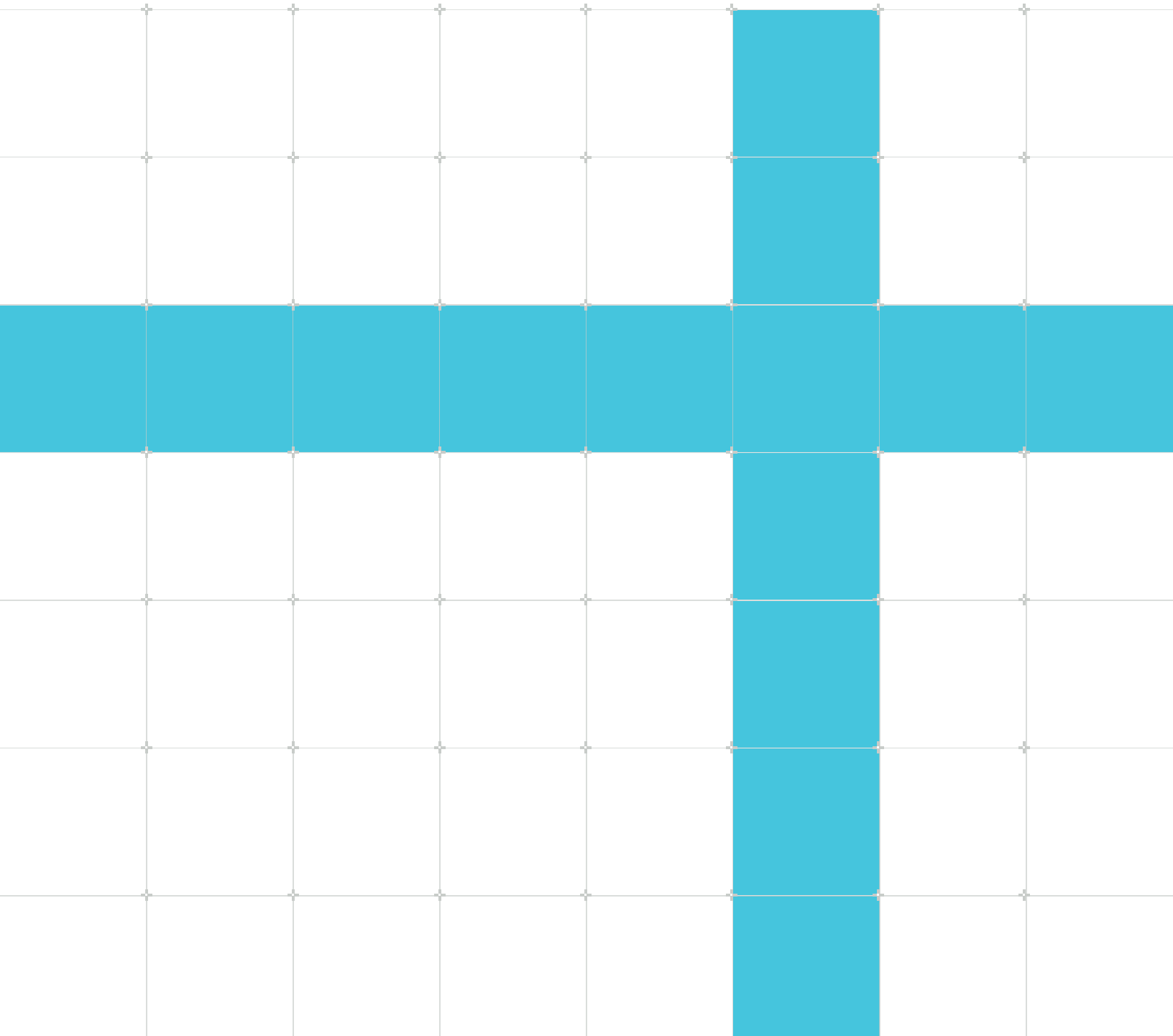

# Get started with Arm Performance Libraries in Arm Compiler for Linux



## Release information

**Document history**

| Issue | Date | Confidentiality | Change |
|---|---|---|---|
| 0100-04 | 30 May 2022 | Non-Confidential | Initial release |
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## Proprietary Notice

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## Confidentiality Status



## Product Status

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# Contents

# 1. Overview

Arm Performance Libraries provides optimized standard core math libraries for high-performance computing applications on Arm processors. The library routines, which are available through both Fortran and C interfaces, cover the following functionality:

- BLAS - Basic Linear Algebra Subprograms (including XBLAS, the Extra Precise BLAS).
- LAPACK 3.11.0 - a comprehensive package of higher level linear algebra routines.
- FFT functions - a set of Fast Fourier Transform routines for real and complex data using the FFTW interface.
- Sparse linear algebra.
- libamath - an optimized collection of mathematical functions (a subset of libm).
- libastring - an optimized collection of string functions (a subset of libc).

Arm Performance Libraries is built with OpenMP across many BLAS, LAPACK, FFT, and sparse routines in order to maximize your performance in multi-processor environments.

Arm Performance Libraries is available for Linux, macOS and Windows.

This tutorial describes how to get started with the version that is part of Arm Compiler for Linux. There is also a stand-alone version of Arm Performance Libraries for Linux. To learn about how to get started with the stand-alone version, see the Get started with stand-alone Arm Performance Libraries for Linux tutorial.

To learn about how to get started with the version of Arm Performance Libraries for macOS, see the Get started with Arm Performance Libraries for macOS tutorial. To learn about how to get started with the version of Arm Performance Libraries for Windows, see the Get started with Arm Performance Libraries for Windows tutorial.

# 2. Installation

The learn.arm.com install guide for Arm Performance Libraries covers the installation basics for all platforms.

Also see Installing Arm Compiler for Linux for detailed documentation on how to perform the installation.

Arm Compiler for Linux, which includes Arm Performance Libraries, can be downloaded from developer.arm.com.

Following installation you should have the environment variable `ARMPL_DIR` set to point to the directory in the Arm Performance Libraries installation which contains (amongst other things) the `include` and `lib` directories containing the header and library files.

# 3. Environment configuration

This section describes how to set up your environment before using Arm Performance Libraries with Arm Compiler for Linux.

## Prerequisites

- You or your administrator has installed Arm Performance Libraries (see Installation).
- The environment module has been made available, as described in Configure.

## Setup

To configure your environment for Arm Performance Libraries:

1. Check which environment modules are available:

```
module avail
```


If you do not see the Arm Compiler for Linux `acfl*` and GCC `gnu*` modulefiles, configure your `MODULEPATH` environment variable to include the installation directory:

```
export MODULEPATH=$MODULEPATH:/opt/arm/modulefiles/
```

2. Load the appropriate module, or modules, for your toolchain.

   For Arm Compiler for Linux, load the compiler modulefile, `acfl`:

```
module load acfl/<version>
```

   For GCC, load both the `gnu` and GCC-compatible `armpl` modulefiles:

```
module load gnu/<version>
module load armpl/<version>
```

# 4. Compile and test the examples

Arm Performance Libraries includes a number of example programs to compile and run.

The examples are located in `${ARMPL_DIR}/examples*`.

Multiple examples directories are provided in the installation. The suffix of the directory name indicates whether the examples inside link to the 32-bit (`_lp64`) or 64-bit (`_ilp64`) integer variants, and sequential (no suffix indicator) or OpenMP (`_mp`) multi-threaded variants, of Arm Performance Libraries.

For more information about the examples provided, see the Arm Performance Libraries Reference Guide.

The default set of examples in the `examples` directory link to the sequential, 32-bit integers variant of Arm Performance Libraries.

Each `examples*` directory contains the following:

- A `Makefile` to build and execute all of the example programs.
- A number of different C examples, `*.c`.
- A number of different Fortran examples, `*.f90`.
- Expected output for each example, `*.expected`.

The Makefile compiles and runs each example, and compares the generated output to the expected output. Any differences are flagged as errors.

Assuming you have first setup your environment to use Arm Performance Libraries (see Environment configuration), then to compile the examples and run the tests:

1. Copy the `examples*` directory somewhere writeable.
2. Change into the `examples*` directory in the writeable location and run `make`:

```
cd path/to/examples*
make
```

The Makefile that uses Arm Compiler for Linux produces output similar to the following sample:

```
Compiling program armplinfo.f90:
armflang -c -mcpu=native -armpl armplinfo.f90 -o armplinfo.o
Linking program armplinfo.exe:
armflang -mcpu=native armplinfo.o -armpl -o armplinfo.exe
Running program armplinfo.exe:
./armplinfo.exe > armplinfo.res

...

Testing: no example difference files were generated.
Test passed OK
```

### Example: fftw_dft_r2c_1d_c_example.c

The `fftw_dft_r2c_1d_c_example.c` example does the following:

- Creates an FFT plan for a one-dimensional, real-to-Hermitian Fourier transform, and a plan for its inverse, Hermitian-to-real transform.
- Executes the first plan to output the transformed values in `y`.
- Destroys the first plan.
- Prints the components of the transform.
- Executes the second plan to get the original data, unscaled.
- Destroys the second plan.
- Outputs the original and restored values, scaled (they should be identical).

```
/*
 * fftw_dft_r2c_1d: FFT of a real sequence
 *
 * ARMPL version 23.10 Copyright ARM 2023
 */

#include <armpl.h>
#include <fftw3.h>
#include <math.h>
#include <stdio.h>

#include "round_eps_to_zero.h"

int main(void) {
#define NMAX 20
    double xx[NMAX];
    double x[NMAX];
    // The output vector is of size (n/2)+1 as it is Hermitian
    fftw_complex y[NMAX / 2 + 1];

    printf("ARMPL example: FFT of a real sequence using fftw_plan_dft_r2c_1d\n");
    printf("-----------------------------------------------------------------\n");
    printf("\n");

    /* The sequence of double data */
    int n = 7;
    x[0] = 0.34907;
    x[1] = 0.54890;
    x[2] = 0.74776;
    x[3] = 0.94459;
    x[4] = 1.13850;
    x[5] = 1.32850;
    x[6] = 1.51370;

    // Use dcopy to copy the values into another array (preserve input)
    cblas_dcopy(n, x, 1, xx, 1);

    // Initialise a plan for a real-to-complex 1d transform from x->y
    fftw_plan forward_plan = fftw_plan_dft_r2c_1d(n, x, y, FFTW_ESTIMATE);
    // Initialise a plan for a complex-to-real 1d transform from y->x (inverse)
    fftw_plan inverse_plan = fftw_plan_dft_c2r_1d(n, y, x, FFTW_ESTIMATE);

    // Execute the forward plan and then deallocate the plan
    /* NOTE: FFTW does NOT compute a normalised transform -
     * returned array will contain unscaled values */
    fftw_execute(forward_plan);
    fftw_destroy_plan(forward_plan);

    printf("Components of discrete Fourier transform:\n");
```

```
    printf("\n");
    int j;
    for (j = 0; j <= n / 2; j++) {
        // Scale factor of 1/sqrt(n) to output normalised data
        double y_real = round_eps_to_zero_d(creal(y[j]) / sqrt(n));
        double y_imag = round_eps_to_zero_d(cimag(y[j]) / sqrt(n));
        printf("%4d   (%7.4f%7.4f)\n", j + 1, y_real, y_imag);
    }

    // Execute the reverse plan and then deallocate the plan
    /* NOTE: FFTW does NOT compute a normalised transform -
     * returned array will contain unscaled values */
    fftw_execute(inverse_plan);
    fftw_destroy_plan(inverse_plan);

    printf("\n");
    printf("Original sequence as restored by inverse transform:\n");
    printf("\n");
    printf("       Original  Restored\n");
    for (j = 0; j < n; j++) {
        double xx_j = round_eps_to_zero_d(xx[j]);
        // Scale factor of 1/n to output normalised data
        double x_j = round_eps_to_zero_d(x[j] / n);
        printf("%4d   %7.4f   %7.4f\n", j + 1, xx_j, x_j);
    }
    return 0;
}
```

To compile and run the example take a copy of the code from one of the examples directories and follow the steps below:

1. To generate an object file, compile the source `fftw_dft_r2c_1d_c_example.c`:

| Compiler | Command |
|---|---|
| armclang | `armclang -c -armpl fftw_dft_r2c_1d_c_example.c -o fftw_dft_r2c_1d_c_example.o` |
| gcc | `gcc -c -I${ARMPL_DIR}/include fftw_dft_r2c_1d_c_example.c -o fftw_dft_r2c_1d_c_example.o` |

2. Link the object code into an executable:

| Compiler | Command |
|---|---|
| armclang | `armclang fftw_dft_r2c_1d_c_example.o -o fftw_dft_r2c_1d_c_example.exe -armpl -lm` |
| gcc | `gcc fftw_dft_r2c_1d_c_example.o -L${ARMPL_DIR}/lib -o fftw_dft_r2c_1d_c_example.exe -larmpl_lp64 -lm` |

The linker and compiler options are:

- `-armpl` provides a shorthand method to specify the required include, library, and link options to Arm Compiler for Linux. The available arguments it accepts are described in the Library selection section.
- `-I${ARMPL_DIR}/include` adds the Arm Performance Libraries location to the include directory search path.
- `-L${ARMPL_DIR}/lib` adds the Arm Performance Libraries location to the library search path.
- `-larmpl_lp64` links against Arm Performance Libraries (serial, 32-bit integer interfaces).
- `-lm` links against the standard math libraries.

3. Run the executable on your Arm system:

```
./fftw_dft_r2c_1d_c_example.exe
```

The executable produces output as follows:

```
ARMPL example: FFT of a real sequence using fftw_plan_dft_r2c_1d
----------------------------------------------------------------

Components of discrete Fourier transform:

   1   ( 2.4836 0.0000)
   2   (-0.2660 0.5309)
   3   (-0.2577 0.2030)
   4   (-0.2564 0.0581)

Original sequence as restored by inverse transform:

       Original  Restored
   1    0.3491    0.3491
   2    0.5489    0.5489
   3    0.7478    0.7478
   4    0.9446    0.9446
   5    1.1385    1.1385
   6    1.3285    1.3285
   7    1.5137    1.5137
```

# 5. Optimized math routines – libamath

libamath contains AArch64-optimized versions of the following scalar `math.h` functions:

- `cosf`, `sinf`, `sincosf`, `tanf`, `acos(f)`, `asin(f)`, `atan(f)`, `atan2(f)`,
- `exp(f)`, `exp2(f)`, `expm1(f)`, `log(f)`, `log2(f)`, `log10(f)`, `log1p(f)`,
- `cosh(f)`, `sinh(f)`, `tanh(f)`, `acosh(f)`, `asinh(f)`, `atanh(f)`,
- `pow(f)`, `erf(f)`, `erfc(f)`, and `cbrt(f)`.

Suffix `f` indicates a single precision implementation, while no suffix indicates double precision and suffix `(f)` indicates that both precisions are available. Linking to libamath ahead of libm will ensure use of these optimized functions.

libamath also contains vectorized versions (Neon and SVE) of all of the common `math.h` functions in libm. It is provided as a static library, `libamath.a`, and as a dynamic library, `libamath.so`.

To provide enhanced performance, these functions are used by Arm Compiler for Linux whenever possible. The compiler automatically links to the libamath library. You do not have to supply any specific compiler options to initiate this behavior.

When using libamath with the GCC compiler, you must explicitly link to the libamath library before linking to libm. For example:

```
gcc code_with_math_routines.c -lamath -lm
```

```
gfortran code_with_math_routines.f -lamath -lm
```

For more information about using the vectorized functions in libamath, see this community.arm.com blog.

# 6. Optimized string routines – libastring

libastring provides a set of replacement `string.h` functions which are optimized for AArch64: `bcmp`, `memchr`, `memcpy`, `memmove`, `memset`, `strchr`, `strchrnul`, `strcmpstrcpy`, `strlen`, `strncmp`, `strnlen`. Linking to libastring ahead of libc ensures use of these optimized functions.

As with the libamath library, to provide enhanced performance by default, Arm Compiler for Linux automatically links to the libastring library before it links to libc. You do not have to supply any specific compiler options to initiate this behavior.

When using libastring with the GCC compiler, you must explicitly link to the libastringlibrary before linking to libc. For example:

```
gcc code_with_string_routines.c -lastring
```

```
gfortran code_with_string_routines.f -lastring
```

# 7. Library selection

Arm Performance Libraries contains multiple different types of library. Your installation contains both dynamic and static libraries, and, in each case, there are serial and multi-threaded libraries. Furthermore, for each of those combinations there are also libraries which take 32-bit integer arguments in function interfaces, and also libraries which take 64-bit integer arguments.

Here we show the options needed to use the different types of library.


Arm Compiler for Linux has a special `-armpl` flag which makes using Arm Performance Libraries easier. We recommend using this flag, although it is still possible to link using the flags given for GCC below.

Supported options and arguments are:

| ACfL flags (Compile & Link) | ACfL or GCC Compile | ACfL or GCC Link | Description |
|---|---|---|---|
| `-armpl` | `-I${ARMPL_DIR}/include_lp64` | `-larmpl` | Link to Arm Performance Libraries with the default settings. |
| `-armpl=lp64`<br><br>(Default) | `-I${ARMPL_DIR}/include_lp64` | `-larmpl_lp64` | Use 32-bit integers. |
| `-armpl=ilp64`<br><br>(Default if using `-i8`) | `-DINTEGER64 -I${ARMPL_DIR}/include_ilp64` | `-DINTEGER64`<br><br>`-larmpl_ilp64` | Use 64-bit integers. |
| `-armpl=sequential`<br><br>(Default) | `-I${ARMPL_DIR}/include_lp64` | `-larmpl_lp64` | Use the single-threaded library. |
| `-armpl=parallel`<br><br>(Default if using `-fopenmp`) | `-I${ARMPL_DIR}/include_lp64` | `-larmpl_lp64_mp` | Use the OpenMP multi-threaded library. |

When using the special ACfL flag, separate multiple arguments using a comma, for example: `-armpl=ilp64,parallel` specifies the multi-threaded library with 64-bit integers.

## Default option and argument behavior

For information about the default behavior of the `-armpl` option and its arguments in Arm Compiler for Linux, see the Arm C/C++ Compiler or Arm Fortran Compiler reference guide.

## Linking against static libraries

The libraries are supplied in both static and dynamic versions, `libarmpl_lp64.a` and `libarmpl_lp64.so`. By default, the commands given above link to the dynamic version of the library, `libarmpl_lp64.so`, if that version exists in the specified directory.

To force linking with the static library, either:

- Use the compiler flag `-static`, for example:

```
armclang driver.c -static -armpl
```

```
gcc driver.c -L${ARMPL_DIR}/lib -static -larmpl_lp64 -lm
```

- Insert the name of the static library in the command line, for example:

```
gcc driver.c ${ARMPL_DIR}/lib/libarmpl_lp64.a -lm
```


The compiler flag distinction given in the tables between using the `include_lp64` directory for 32-bit integer interfaces and using `include_ilp64` for 64-bit integers only actually matters for users of the interface blocks in the Fortran pre-compiled modules (e.g. `armpl_blas.mod`). For C users and Fortran users who are not using the interface blocks (or are re-compiling the modules from source), it does not matter which include directory you choose to use. For more information, see the Arm Performance Libraries Reference Guide.

# 8. Further information

The following links contain detailed documentation about different aspects of using Arm Performance Libraries:

- The learn.arm.com install guide shows how to install Arm Performance Libraries on all supported platforms.
- See the developer.arm.com downloads page for stand-alone versions of Arm Performance Libraries for the full list of supported platforms.
- Arm Compiler for Linux, which includes Arm Performance Libraries, can also be downloaded from developer.arm.com.
- Arm Performance Libraries Reference Guide provides comprehensive documentation for all functions.
- Arm Compiler for Linux C/C++ Reference Guide provides compiler documentation for C/C++ users.
- Arm Compiler for Linux Fortran Reference Guide provides compiler documentation for Fortran users.
- If you have any questions or queries about using Arm Performance libraries please post a message on the Compilers and Libraries support forum. See below for guidance on how to do this effectively.

## Reporting issues

To get help with any issue that you are experiencing, it helps to report information about the version of Arm Performance Libraries that you are using and the system that you are running on.

You can obtain the necessary system and library information by running the `libarmpl.so` file (or any of the other `libarmpl*.so` files). You can find the `libarmpl.so` file in the `${ARMPL_DIR}/lib` directory of your installation.

You should load the Arm Performance Libraries environment module for your system before running `libarmpl.so`.

```
module load armpl
${ARMPL_DIR}/lib/libarmpl.so
```


We also recommend using perf-libs-tools, which is an Open Source project that can be used to profile your usage of Arm Performance Libraries, and also includes some scripts to visualize the data it produces. Providing the output reports from a perf-libs-tools run of your application when posting on the forum is incredibly useful, especially when reporting performance-related issues.

## Other releases of Arm Performance Libraries

Arm Performance Libraries is also available:

- As stand-alone Linux releases, compatible with GCC and NVHPC.
- For macOS, compatible with LLVM.
- For Windows, compatible with MSVC and LLVM.