



Get started with Arm Performance Libraries (macOS version)

Version 23.10

Non-Confidential

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Issue 00

109362_2310_00_en



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Release information

Document history

Issue	Date	Confidentiality	Change
2310-00	30 September 2023	Non-Confidential	Updates coinciding with Arm PL 23.10

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(LES-PRE-20349|version 21.0)

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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.

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 of Arm Performance Libraries for macOS. To learn about how to get started with the version of Arm Performance Libraries for Linux, see the [Get started with Arm Performance Libraries for Linux 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](https://learn.arm.com/install-guide-for-Arm-Performance-Libraries) covers the installation basics for all platforms.

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 macOS.

Prerequisites

- You or your administrator has installed Arm Performance Libraries (see [Installation](#)).
- You may need to ensure you have compatible compilers installed on your system, as described below.

C/C++ users are advised to install `clang` version 17 or above, including support for OpenMP run time libraries. We suggest using [Homebrew](#).

```
brew install llvm@17
```

`libomp.dylib` may be installed in `/opt/homebrew/opt/llvm` by default when installing via Homebrew as shown above. If not,

```
brew install libomp
```

will install it in `/opt/homebrew/opt/libomp/lib`.

Alternatively, `libomp.dylib` is provided in `${ARMPL_DIR}/lib`.

Users who wish to link to the libraries only from C/C++ will still need to link to the Fortran runtime libraries, `libFortranDecimal.a` and `libFortranRuntime.a` which are provided in `${ARMPL_DIR}/lib`.

Fortran users, those who have Fortran source code to compile, should download and build the LLVM Fortran compiler for macOS. The source repository can be downloaded from:

```
https://github.com/llvm/llvm-project.git
```

Setup

To configure your environment for Arm Performance Libraries:

Set the following environment variables:

```
export ARMPL_DIR=<location of armpl_<version> directory>  
export OPENMP_DIR=<location of libomp.dylib>
```




A bash script, `armpl_env_vars.sh`, is provided that can be sourced to set these environment variables. To use:

```
source ${ARMPL_DIR}/armpl_env_vars.sh
```

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 C 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 c_examples
```

The `Makefile` produces output similar to the following sample:

```
Compiling program armpl_dgemm_interleave_batch_c_example.c:
clang -c -I/.../armpl_23.10_flang-new clang_17/include
-std=c99 armpl_dgemm_interleave_batch_c_example.c -o
armpl_dgemm_interleave_batch_c_example.o
Linking program armpl_dgemm_interleave_batch_c_example.exe:
clang armpl_dgemm_interleave_batch_c_example.o -L/.../armpl_23.10_flang-
new clang_17/lib -larmpl -lFortranRuntime -lFortranDecimal -lm -lc++ -o
armpl_dgemm_interleave_batch_c_example.exe
Running program armpl_dgemm_interleave_batch_c_example.exe:
ARMPL example: interleave-batch matrix multiplication
-----
blas_sum = 3.955600e+06
```

```
ib_sum = 3.955600e+06
...
```

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
 *
 * ARMPPL 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("ARMPPL 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
clang	<code>clang -c -I\${ARMPL_DIR}/include fftw_dft_r2c_1d_c_example.c -o fftw_dft_r2c_1d_c_example.o</code>

2. Link the object code into an executable:

Compiler	Command
clang	<code>clang fftw_dft_r2c_1d_c_example.o -L\${ARMPL_DIR}/lib -o fftw_dft_r2c_1d_c_example.exe - larmpl_lp64 -lFortranRuntime -lFortranDecimal -lm -lc++</code>

The linker and compiler options are:

- `-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).
- `-lFortranRuntime -lFortranDecimal` links against the Fortran runtime libraries (supplied with Arm Performance Libraries).
- `-lm` links against the standard math libraries.

- `-lc++` links against the standard C++ 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. 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.

Compile	Link	Description
<code>-I\${ARMPL_DIR}/include_lp64</code>	<code>-larmpl_lp64</code>	Use 32-bit integers, single-threaded library.
<code>-DINTEGER64 -I\${ARMPL_DIR}/include_ilp64</code>	<code>-DINTEGER64</code> <code>-larmpl_ilp64</code>	Use 64-bit integers, single-threaded library.
<code>-I\${ARMPL_DIR}/include_lp64</code>	<code>-larmpl_lp64</code>	Use 32-bit integers, multi-threaded (OpenMP) library.
<code>-I\${ARMPL_DIR}/include_lp64</code>	<code>-larmpl_lp64_mp</code>	Use 64-bit integers, multi-threaded (OpenMP) library.

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.

Insert the name of the static library in the command line to force linking against it. For example:

```
clang driver.c ${ARMPL_DIR}/lib/libarmpl_lp64.a -lFortranRuntime -lFortranDecimal -lm -lc++
```



Linking fully static binaries is not supported on macOS, so do not try to link using the `-static` linker flag.



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](#).

6. Further information

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

- The [learn.arm.com install guide](https://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](https://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.
- 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.

Please ensure you tell us which version of macOS and the version of LLVM (`clang` or `clang-new`) you are using. To find the version of macOS that is installed on your system, from the Apple menu in the top-left corner of your screen select “About This Mac”. To find the version of LLVM you are using, from a terminal type:

```
clang --version
```



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 part of Arm Compiler for Linux.](#)
- [As stand-alone Linux releases, compatible with GCC and NVHPC.](#)
- [For Windows, compatible with MSVC and LLVM.](#)