FreeRTOS

Qualification Guide

FreeRTOS: Qualification Guide

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AWS Qualification Program for FreeRTOS

What is FreeRTOS

Developed in partnership with the world's leading chip companies over a 15-year period, and now downloaded every 175 seconds, FreeRTOS is a market-leading real-time operating system (RTOS) for microcontrollers and small microprocessors. Distributed freely under the MIT open source license, FreeRTOS includes a kernel and a growing set of libraries suitable for use across all industry sectors. FreeRTOS is built with an emphasis on reliability and ease of use.

FreeRTOS includes libraries for connectivity, security, and over-the-air (OTA) updates. FreeRTOS also includes demo applications that show FreeRTOS features on qualified boards.

FreeRTOS is an open-source project. You can download the source code, contribute changes or enhancements, or report issues on the GitHub site at https://github.com/aws/amazon-freertos. We release FreeRTOS code under the MIT open source license, so you can use it in commercial and personal projects.

We also welcome contributions to the FreeRTOS documentation (*FreeRTOS User Guide*, *FreeRTOS Porting Guide*, and *FreeRTOS Qualification Guide*). The markdown source for the documentation is available at https://github.com/awsdocs/aws-freertos-docs. It is released under the Creative Commons (CC BY-ND) license.

The FreeRTOS kernel and components are released individually and use semantic versioning. Integrated FreeRTOS releases are made periodically. All releases use date-based versioning with the format YYYYMM.NN, where:

- Y represents the year.
- M represents the month.
- N represents the release order within the designated month (00 being the first release).

For example, a second release in June 2021 would be 202106.01.

Previously, FreeRTOS releases used semantic versioning for major releases. Although it has moved to date-based versioning (FreeRTOS 1.4.8 updated to FreeRTOS AWS Reference Integrations 201906.00), the FreeRTOS kernel and each individual FreeRTOS library still retain semantic versioning. In semantic versioning, the version number itself (X.Y.Z) indicates whether the release is a major, minor, or point release. You can use the semantic version of a library to assess the scope and impact of a new release on your application.

LTS releases are maintained differently than other release types. Major and minor releases are frequently updated with new features in addition to defect resolutions. LTS releases are only updated with changes to address critical defects and security vulnerabilities. No new features are introduced in a given LTS release after launch. They are maintained for at least three calendar years after release, and provide device manufacturers the option to use a stable baseline as opposed to a more dynamic baseline represented by major and minor releases.

What is the AWS Qualification Program for FreeRTOS?

The AWS Device Qualification Program for FreeRTOS validates pre-integrated FreeRTOS projects ported to microcontroller-based boards, giving developers confidence that the FreeRTOS port behaves correctly and consistently with AWS IoT.

Those in the Amazon Partner Network can use the AWS Device Qualification Program to officially qualify a microcontroller (MCU) development board for FreeRTOS.

Qualified boards are eligible for listing on the AWS Partner Device Catalog.

To qualify a device for FreeRTOS, you must port FreeRTOS to your device, and then follow the AWS Device Qualification Program steps. For information, see the AWS Device Qualification Program page and the AWS Device Qualification Program Guide.

For information about qualifying your device for FreeRTOS, see Qualifying Your Device (p. 4).

Qualification FAQs

Q: *Can I qualify an MCU that doesn't have Wi-Fi or ethernet?*

A: Yes. There are qualified MCUs that use external Wi-Fi modules and offload various functions to the Wi-Fi module, including TCP/IP and TLS. An example is the STM32L4 Discovery Kit that uses an Inventek Wi-Fi module. Follow the Device Qualification Program submittal process and let us know how we can help with your efforts.

Q: *If a version of FreeRTOS is released after I have started porting a previous version, do I need to start over using the latest version?*

A: Always start porting the latest version of FreeRTOS. If we release a new version of FreeRTOS while you are working on your port, you can still qualify on the previous version.

Q: *My board uses a kernel architecture that I have modified and that is not part of the official FreeRTOS release. Can I still qualify?*

A: Unfortunately, only official kernel ports are accepted. These are available from GitHub or SourceForge. If you have an unsupported architecture or additional functionality to add to an existing kernel port, contact your local APN representative.

Q: *If I want to update a port listed on the Device Catalog to a newer version of FreeRTOS, do I need to requalify all over again?*

A: After you have updated your port, run the AWS IoT Device Tester again and check the FreeRTOS Qualification Checklist (p. 22) to see if any items have been impacted (especially the Getting Started Guide). Submit a Device Qualification Program ticket with a copy of your passing log to update the Device Catalog listing to point to your new port.

Q: *My device does not support Wi-Fi. Is a port of the FreeRTOS Wi-Fi library required to qualify for FreeRTOS?*

A: The primary requirement is that your device can connect to the AWS Cloud. If your device can connect to the AWS Cloud across a secure ethernet connection, the Wi-Fi library is not a requirement.

Q: *My device does not support Bluetooth Low Energy or over-the-air (OTA) updates. Are ports for these FreeRTOS libraries required to qualify for FreeRTOS?*

A: Bluetooth Low Energy and OTA ports are optional for qualification.

Q: *My board does not have on-chip TCP/IP functionality. Is a particular TCP/IP stack required for FreeRTOS qualification?*

> A: If your board does not have on-chip TCP/IP functionality, you can use either the FreeRTOS+TCP TCP/IP stack or the latest version of the lwIP TCP/IP stack to pass TCP/IP qualification requirements. For the latest version of lwIP supported by FreeRTOS, see the changelog.md file on the GitHub website. For more information, see Porting a TCP/IP Stack in the *FreeRTOS Porting Guide*.

Q: *Is a particular TLS stack required for qualification?*

> A: FreeRTOS supports mbedTLS and off-chip TLS implementations, such as those found on some network processors. No matter which TLS implementation is used by your device's port of FreeRTOS, the port must pass the Device Tester validation tests for TLS. For more information, see Porting the TLS Library in the *FreeRTOS Porting Guide*.

Q: *Does my device need to pass all of the AWS IoT Device Tester validation tests to qualify? Is there a way to qualify without passing all of the tests?*

> A: Your device must pass all of the required validation tests to qualify for FreeRTOS. The only exceptions are for Wi-Fi, Bluetooth Low Energy, and OTA.

Q: *My device uses only one of the protocols (HTTP, MQTT) and only one of the available communication channels (Wi-Fi, Ethernet, BLE). If all the OTA related IDT tests pass using just one protocol-communication channel combination, then will my device get listed as OTA qualified in the device catalog?*

> A: Yes. We encourage you to get other combinations qualified on your device as well, if possible. In this way, you can provide support for more customer use cases.

Q: *We will be hosting our FreeRTOS port in our own repo as per the qualification requirements. What should we include in the repo in terms of folders and demos to support?*

> A: Please host all the files and folders necessary to make the port work as an out of the box experience for a customer who downloads it from the repository. You should include your entire `freertos_kernel`, `libraries`, and `tools` folders, along with a `docs` folder for your documents, a `projects` folder for your IDE projects, and a `vendors` folder for your vendor-specifc files. Also include your entire demo folder. (The coreMQTT Mutual Authentication demo must be supported, however, other demos are at your discretion. Also, the `tools` folder is not required, however, we recommend that you host this folder to assist customers with testing.)

If you have questions about qualification that are not answered on this page or in the rest of the FreeRTOS Qualification Guide, contact your AWS representative or the FreeRTOS engineering team.

Documentation history

See the *Revision history of FreeRTOS porting and qualification documentation* at Porting FreeRTOS to your IoT device in the *FreeRTOS Porting Guide*.

Qualifying Your Device

To qualify your device for FreeRTOS

1. Port the FreeRTOS libraries to your device.

   Note
   Currently, ports of the FreeRTOS OTA and Bluetooth Low Energy libraries are not required for qualification.
   If your device does not support Wi-Fi, you can use an ethernet connection to connect to the AWS Cloud instead. A port of the FreeRTOS Wi-Fi library is not necessarily required.

   For instructions on porting FreeRTOS to your device, see the FreeRTOS Porting Guide.
2. Validate your ports with AWS IoT Device Tester for FreeRTOS.

   When using Device Tester to validate your ports for qualification, you must specify information in the `features` attribute of the `device.json` configuration file about the following ports:

   - TCP/IP

   ```
   {
       "name": "TCP/IP",
       "value": "On-chip | Offloaded | No"
   }
   ```

   - TLS

   ```
   {
       "name": "TLS",
       "value": "On-chip | Offloaded | No"
   }
   ```

   - Wi-Fi

   ```
   {
       "name": "WIFI",
       "value": "Yes | No"
   }
   ```

   - OTA

   ```
   {
       "name": "OTA",
       "value": "Yes | No"
   }
   ```

   Device Tester uses this information to determine which tests to run against your ported FreeRTOS code. Device Tester runs all other required library port tests by default.

   For information about AWS IoT Device Tester for FreeRTOS, see Using AWS IoT Device Tester for FreeRTOS in the FreeRTOS User Guide.
3. Create the following for qualification submission:

- A "Hello World" demo application that publishes messages from your device to the AWS Cloud over MQTT.

  For information, see Setting up a hello world demo (p. 5).
- A "Getting Started with FreeRTOS" guide for your device.

  For information, see Creating a getting started with FreeRTOS guide for your device (p. 7).
- A `CMakeLists.txt` file for building FreeRTOS applications for your device.

  > **Note**
  > A CMake list file is not required to qualify a board through the AWS Device Qualification Program. The file is only required for listing devices on the FreeRTOS Console. The file is also required to build project files for your platform using CMake.

  For information, see Creating a CMakeLists.txt file for your platform (p. 9).
- A list of detailed information for your hardware platform.

  For information, see FreeRTOS Qualification Checklist (p. 22).
- An appropriate open source license file for your device's FreeRTOS port.

  For information, see Providing an open source license for your code (p. 21).
- (For boards qualifying for OTA updates) Instructions for code-signing.

  For examples, see Create a Code-Signing Certificate in the FreeRTOS User Guide.
- (For boards qualifying for OTA updates that use custom bootloader) Information and instructions on the custom bootloader application.

  For a list of requirements, see Porting the Bootloader Demo in the FreeRTOS Porting Guide.

These items are required for your device to be listed on the FreeRTOS console, for your device's code to be on GitHub, and for your device to receive Getting Started documentation support.

4. Submit your qualified board for listing in the AWS Partner Device Catalog through the Device Listing Portal on APN Partner Central. All submissions require an AWS IoT Device Tester test result file that indicates that you passed all mandatory test cases. You must be a registered APN Partner to submit your board for listing.

You can use the FreeRTOS Qualification Checklist (p. 22) to keep track of the list of required steps for qualification.

Setting up a hello world demo

To qualify for FreeRTOS, set up a Hello World demo application that runs on your qualified device. This demo publishes messages from your device to the AWS Cloud over MQTT.

To set up the hello world demo

1. Follow the instructions in Configuring the FreeRTOS download for demos (p. 6) to configure the directory structure of your FreeRTOS download to fit your device.
2. Follow the instructions in Creating the demo project (p. 6) to create a demo project in your IDE.

After you set up the demo, create a "Getting Started with FreeRTOS" guide for your device. This guide walks users through setting up your device to run the Hello World demo.

Configuring the FreeRTOS download for demos

Under the download's root directory (*freertos*), the vendors folder is structured as follows:

```
vendors
+ - vendor    (Template, to be renamed to the name of the MCU vendor)
    + - boards
    |   + - board    (Template, to be renamed to the name of the development board)
    |       + - aws_demos
    |       + - aws_tests
    |       + - CMakeLists.txt
    |       + - ports
    + - driver_library    (Template, to be renamed to the library name)
        + - driver_library_version    (Template, to be renamed to the library version)
```

The *vendor* and *board* folders are template folders that we provide to make it easier to create demo and test projects. Their directory structure ensures that all demo and test projects have a consistent organization.

The *aws_demos* folder has the following structure:

```
vendors/vendor/boards/board/aws_demos
+ - application_code    (Contains main.c, which contains main())
|   + - vendor_code    (Contains vendor-supplied, board-specific files)
|   + - main.c    (Contains main())
+ - config_files    (Contains FreeRTOS config files)
```

To configure the demo project files

Copy main.c and main.h files for the demo application to the application_code folder. You can reuse the main.c from the aws_tests project that you used to test your ports.

1. Save any required vendor-supplied, board-specific libraries to the *vendor*_code folder.

   Important
   Do not save vendor-supplied libraries that are common across a target board's MCU family to any subdirectories of aws_tests or aws_demos.
2. Replace *vendor* in the *vendor*_code folder with the name of the vendor.
3. Rename the *board* folder to the name of the development board.

After you configure the demo project files, you can create the project in the IDE. For instructions, see Creating the demo project (p. 6).

If you are creating a CMake listfile (p. 9), make sure that you provide a CMakelist entry for the demo project.

Creating the demo project

After you configure your FreeRTOS download, you can create an IDE project with the required project structure for the Hello World demo.

Follow the instructions below to create an IDE project with the required IDE project structure for demo applications.

Important
If you are using an Eclipse-based IDE, do not configure the project to build all the files in any folder. Instead, add source files to a project by linking to each source file individually.

1. Create a project named `aws_demos` and save the project to the `projects/`*`vendor`*`/`*`board`*`/`*`ide`* directory.
2. In your IDE, create two virtual folders under `aws_demos`:

   - `application_code`
   - `config_files`

   Under `aws_demos`, there should now be two virtual subdirectories in the IDE project: `application_code` and `config_files`.

   Note
   Eclipse generates an additional `includes` folder. This folder is not a part of the required structure.
3. Import all of the folders and files in `aws_demos/application_code` and its subdirectories into the `application_code` virtual folder in your IDE.
4. Import all of the files from `aws_demos/config_files` into the `config_files` virtual folder in your IDE.
5. Import all of the folders and files from the following directories into the `application_code` virtual folder in your IDE:

   - *`freertos`*`/demos/demo_runner`
   - *`freertos`*`/demos/coreMQTT`
   - *`freertos`*`/libraries/.../provisioning/src`
6. Import the *`freertos`*`/demos/include` directory and its contents into the `application_code` virtual folder in your IDE.
7. Import the following directories and their contents into the `aws_demos` IDE project:

   Note
   Only import the files and directories that apply to your platform and port.

   - *`freertos`*`/libraries`
   - *`freertos`*`/freertos_kernel`
   - *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/`*`driver_library`*`/`*`driver_library_version`*
8. Open your project's IDE properties, and add the following paths to your compiler's include path:

   - *`freertos`*`/demos/include`
   - *`freertos`*`/freertos_kernel/portable/`*`compiler`*`/`*`architecture`*
   - *`freertos`*`/libraries/3rdparty/mbedtls/include`
   - *`freertos`*`/vendors/`*`vendor`*`/boards/`*`board`*`/aws_demos/config_files`
   - Any paths required for vendor-supplied driver libraries.

Creating a getting started with FreeRTOS guide for your device

To qualify for FreeRTOS, you need to create a Getting Started with FreeRTOS guide for your device. This guide walks users through setting up the hardware and development environment for developing applications for FreeRTOS devices, and building, running, and flashing the FreeRTOS Hello World demo on a device.

This guide must be available to customers on a public website. The URL to the guide is a requirement for listing a qualified board in the AWS Partner Device Catalog.

Your guide must include the following instructions:

- Setting up the device hardware.
- Setting up the development environment.
- Building and running the demo project.
- Debugging.
- Troubleshooting.

We also recommend that your guide includes:

- A link to the MCU datasheet.
- A Printed Circuit Board (PCB) schematic.
- A default image boot up console log.

> **Important**
> Where instructions differ by operating system, you must provide instructions for Windows, Linux, and macOS operating systems.

Follow the Getting started guide template (p. 8) when you write the guide for your board. You can find examples of published guides for other qualified boards in the FreeRTOS User Guide.

Getting started guide template

Write an overview that provides a brief description of the board. This section should answer the following questions:

- Which hardware is required to run the FreeRTOS Hello World demo?

  Provide links to pages on your company website for more detail.
- Which IDEs are supported for developing applications for the board?

  Provide links to IDE user guides and download pages.
- Which toolchains and other software utilities are required for development?

  Provide links to user guides and download pages.
- Are there any other prerequisites for getting started with FreeRTOS on the board?

  Provide links to purchasing pages, user guides, and download pages.

Setting up your hardware

In this section, provide instructions for setting up the platform's hardware. Make sure that you provide links to any user guides or other documentation for setting up hardware.

These instructions include the following:

- Configuring jumper settings.
- Downloading and installing drivers.

  Provide links to download pages and other documentation for supported driver versions.
- Connecting the board to a computer.
- Any other steps required to set up the hardware.

Setting up the development environment

In this section, provide instructions for setting up the platform's supported development environment. Make sure that you provide links to any download pages, user guides, or other documentation for each item.

These instructions include the following:

- Establishing a serial connection.
- Downloading and installing the toolchain.
- Downloading and installing a supported IDE.
- Any other software that is required to develop and debug applications for the device.

Build and run the FreeRTOS demo project

Build the FreeRTOS demo

In this section, provide instructions for building the FreeRTOS demo code in a supported IDE, or with supported command line tools.

> **Note**
> You must provide instructions for building the demo application on your board with CMake.

Run the FreeRTOS demo project

In this section, provide instructions for flashing and running the FreeRTOS demo code on your board.

Debugging

In this section, provide instructions for using on-board or external debuggers.

Troubleshooting

In this section, provide troubleshooting tips for resolving common or potential problems.

Creating a CMakeLists.txt file for your platform

A `CMakeLists.txt` file is used to list your device on the FreeRTOS console, and it makes it possible for developers to build FreeRTOS code for the device without an IDE.

> **Note**
> A CMake list file is not required to qualify a board through the AWS Device Qualification Program. The file is only required for listing devices on the FreeRTOS Console.

For more information about the CMake build system, see CMake.org.

Follow the instructions in Creating a list file for your platform from the CMakeLists.txt template (p. 10) to create a CMake list file from the template provided with FreeRTOS.

> **Important**
> Before you submit your CMake list file, you must verify that you can use the file to build the FreeRTOS test project and the Hello World demo project with CMake.

For instructions, see Building FreeRTOS with CMake (p. 17).

Prerequisites

Make sure that your host machine meets the following prerequisites before you continue:

- Your device's compilation toolchain must support the machine's operating system. CMake supports all versions of Windows, macOS, and Linux.

  Windows subsystem for Linux (WSL) is not supported. Use native CMake on Windows machines.
- You must have CMake version 3.13 or later installed.

  You can download the binary distribution of CMake from CMake.org.

  Note
  If you download the binary distribution of CMake, make sure that you add the CMake executable to the PATH environment variable before you use CMake from command line.

  You can also download and install CMake using a package manager, like homebrew on macOS, and scoop or chocolatey on Windows.

  Note
  The CMake package versions in the package managers for many Linux distributions are out-of-date. If your distribution's package manager does not include the latest version of CMake, you can try `linuxbrew` or `nix`.
- You must have a compatible native build system.

  CMake can target many native build systems, including GNU Make or Ninja. Both Make and Ninja can be installed with package managers on Linux, macOS, and Windows. If you are using Make on Windows, you can install a standalone version from Equation, or you can install MinGW, which bundles Make.

  Note
  The Make executable in MinGW is called `mingw32-make.exe`, instead of `make.exe`.

  We recommend that you use Ninja, because it is faster than Make and also provides native support to all desktop operating systems.

Creating a list file for your platform from the CMakeLists.txt template

A `CMakeLists.txt` template file is provided with FreeRTOS, under `*freertos*/vendors/*vendor*/boards/*board*/CMakeLists.txt`.

The `CMakeLists.txt` template file consists of four sections:

- FreeRTOS console metadata (p. 11)
- Compiler settings (p. 12)
- FreeRTOS portable layers (p. 13)
- FreeRTOS demos and tests (p. 16)

Follow the instructions to edit these four sections of the list file to match your platform. You can refer to the `CMakeLists.txt` files for other qualified vendor boards under `*freertos*/vendors` as examples.

Two primary functions are called throughout the file:

`afr_set_board_metadata(`*`name value`*`)`

This function defines metadata for the FreeRTOS console. The function is defined in *`freertos`*`/tools/cmake/afr_metadata.cmake`.

`afr_mcu_port(`*`module_name`*` [<DEPENDS> [`*`targets`*`...]])`

This function defines the portable-layer target associated with a FreeRTOS module (that is, library). It creates a CMake `GLOBAL INTERFACE IMPORTED` target with a name of the form `AFR:`*`module_name`*`::mcu_port`. If `DEPENDS` is used, additional targets are linked with `target_link_libraries`. The function is defined in *`freertos`*`/tools/cmake/afr_module.cmake`.

FreeRTOS console metadata

The first section of the template file defines the metadata that is used to display a board's information in the FreeRTOS console. Use the function `afr_set_board_metadata(`*`name value`*`)` to define each field listed in the template. This table provides descriptions of each field.

Field Name	Value Description
`ID`	A unique ID for the board.
`DISPLAY_NAME`	The name of the board as you want it displayed on the FreeRTOS console.
`DESCRIPTION`	A short description of the board for the FreeRTOS console.
`VENDOR_NAME`	The name of the vendor of the board.
`FAMILY_NAME`	The name of the board's MCU family.
`DATA_RAM_MEMORY`	The size of the board's RAM, followed by abbreviated units. For example, use KB for kilobytes.
`PROGRAM_MEMORY`	The size of the board's program memory, followed by abbreviated units. For example, use "MB" for megabytes.
`CODE_SIGNER`	The code-signing platform used for OTA updates. Use AmazonFreeRTOS-Default for SHA256 hash algorithm and ECDSA encryption algorithm. If you want to use a different code-signing platform, contact us.
`SUPPORTED_IDE`	A semicolon-delimited list of IDs for the IDEs that the board supports.
`IDE_`*`ID`*`_NAME`	The name of the supported IDE. Replace *`ID`* with the ID listed for the IDE in the `SUPPORTED_IDE` field.
`IDE_`*`ID`*`_COMPILER`	A semicolon-delimited list of names of supported compilers for the supported IDE. Replace *`ID`* with the ID listed for the IDE in the `SUPPORTED_IDE` field.

Field Name	Value Description
KEY_IMPORT_PROVISIONING	Set to TRUE if the board demo project imports the credentials from the pre-provisioned aws_clientcredential_keys.h header file; in this case, **Quick Connect** will be enabled in the FreeRTOS console. Set to FALSE if the intended board provisioning mechanism is JITR/JITP or multi-account registration; in this case, **Quick Connect** will be disabled in the FreeRTOS console.

Compiler settings

The second section of the template file defines the compiler settings for your board. To create a target that holds the compiler settings, call the afr_mcu_port function with compiler in place of the *module_name* to create an INTERFACE target with the name AFR::compiler::mcu_port. The kernel publicly links to this INTERFACE target so that the compiler settings are transitively populated to all modules.

Use the standard, built-in CMake functions to define the compiler settings in this section of the list file. As you define the compiler settings, follow these best practices:

- Use target_compile_definitions to provide compile definitions and macros.
- Use target_compile_options to provide compiler flags.
- Use target_include_directories to provide include directories.
- Use target_link_options to provide linker flags.
- Use target_link_directories to provide linker-search directories.
- Use target_link_libraries to provide libraries to link against.

Note
If you define the compiler settings somewhere else, you don't need to duplicate the information in this section of the file. Instead, call afr_mcu_port with DEPENDS to bring in the target definition from another location.
For example:

```
# your_target is defined somewhere else. It does not have to be in the same file.
afr_mcu_port(compiler DEPENDS your_target)
```

When you call afr_mcu_port with DEPENDS, it calls target_link_libraries(AFR::*module_name*::mcu_port INTERFACE *your_targets*), which populates the compiler settings for the required AFR::compiler::mcu_port target.

Using multiple compilers

If your board supports multiple compilers, you can use the AFR_TOOLCHAIN variable to dynamically select the compiler settings. This variable is set to the name of the compiler you are using, which should be same as the name of the toolchain file found under *freertos*/tools/cmake/toolchains.

For example:

```
if("${AFR_TOOLCHAIN}" STREQUAL "arm-gcc")
    afr_mcu_port(compiler DEPENDS my_gcc_settings).
```

```
elseif("${AFR_TOOLCHAIN}" STREQUAL "arm-iar")
    afr_mcu_port(compiler DEPENDS my_iar_settings).
else()
    message(FATAL_ERROR "Compiler ${AFR_TOOLCHAIN} not supported.")
endif()
```

Advanced compiler settings

If you want to set more advanced compiler settings, such as setting compiler flags based on programming language, or changing settings for different release and debug configurations, you can use CMake generator expressions.

For example:

```
set(common_flags "-foo")
set(c_flags "-foo-c")
set(asm_flags "-foo-asm")
target_compile_options(
    my_compiler_settings INTERFACE
    $<$<COMPILE_LANGUAGE:C>:${common_flags} ${c_flags}> # This only have effect on C files.
    $<$<COMPILE_LANGUAGE:ASM>:${common_flags} ${asm_flags}> # This only have effect on ASM
 files.
)
```

CMake generator expressions are not evaluated at the configuration stage, when CMake reads list files. They are evaluated at the generation stage, when CMake finishes reading list files and generates build files for the target build system.

FreeRTOS portable layers

The third section of the template file defines all of the portable layer targets for FreeRTOS (that is, libraries).

You must use the `afr_mcu_port(module_name)` function to define a portable layer target for each FreeRTOS module that you plan to implement.

You can use any CMake functions you want, as long as the `afr_mcu_port` call creates a target with a name that provides the information required to build the corresponding FreeRTOS module.

The `afr_mcu_port` function creates a GLOBAL INTERFACE IMPORTED library target with a name of the form `AFR::module_name::mcu_port`. As a `GLOBAL` target, it can be referenced in CMake list files. As an `INTERFACE` target, it is not built as a standalone target or library, but compiled into the corresponding FreeRTOS module. As an `IMPORTED` target, its name includes a namespace (`::`) in the target name (for example, `AFR::kernel::mcu_port`).

Modules without corresponding portable layer targets are disabled by default. If you run CMake to configure FreeRTOS, without defining any portable layer targets, you should see the following output:

```
FreeRTOS modules:
  Modules to build:
  Disabled by user:
  Disabled by dependency:  kernel, posix, pkcs11, secure_sockets, mqtt, ...

  Available demos:
  Available tests:
```

As you update the `CMakeLists.txt` file with porting layer targets, the corresponding FreeRTOS modules are enabled. You should also be able to build any FreeRTOS module whose dependency requirements are subsequently satisfied. For example, if the coreMQTT library is enabled, the Device Shadow library is also enabled, because its only dependency is the coreMQTT library.

Note
The FreeRTOS kernel dependency is a minimum requirement. The CMake configuration fails if the FreeRTOS kernel dependency is not satisfied.

Setting up the kernel porting target

To create the kernel porting target (`AFR::kernel::mcu_port`), call `afr_mcu_port` with the module name `kernel`. When you call `afr_mcu_port`, specify the targets for the FreeRTOS portable layer and driver code. After you create the target, you can provide the dependency information and the FreeRTOS portable layer and driver code information for the target to use.

Follow these instructions to set up the kernel porting target.

To set up the kernel porting target

1. Create a target for the driver code.

   For example, you can create a `STATIC` library target for the driver code:

```
add_library(my_board_driver STATIC ${driver_sources})

# Use your compiler settings
target_link_libraries(
    my_board_driver
    PRIVATE AFR::compiler::mcu_port
# Or use your own target if you already have it.
#   PRIVATE ${compiler_settings_target}
)

target_include_directories(
    my_board_driver
    PRIVATE "include_dirs_for_private_usage"
    PUBLIC "include_dirs_for_public_interface"
)
```

   Or you can create an `INTERFACE` library target for the driver code:

```
# No need to specify compiler settings since kernel target has them.
add_library(my_board_driver INTERFACE ${driver_sources})
```

   Note
   An `INTERFACE` library target does not have build output. If you use an `INTERFACE` library target, the driver code is compiled into the kernel library.

2. Configure the FreeRTOS portable layer:

```
add_library(freertos_port INTERFACE)
target_sources(
    freertos_port
    INTERFACE
        "${AFR_MODULES_DIR}/freertos_kernel/portable/GCC/ARM_CM4F/port.c"
        "${AFR_MODULES_DIR}/freertos_kernel/portable/GCC/ARM_CM4F/portmacro.h"
        "${AFR_MODULES_DIR}/freertos_kernel/portable/MemMang/heap_4.c"
)
target_include_directories(
    freertos_port
    INTERFACE
        "${AFR_MODULES_DIR}/freertos_kernel/portable/GCC/ARM_CM4F"
        "${include_path_to_FreeRTOSConfig_h}
)
```

Note
You can also configure the FreeRTOS portable layer by specifying these source files and their include directories directly in the `AFR::kernel::mcu_port` target.

3. Create the kernel portable layer target:

```
# Bring in driver code and freertos portable layer dependency.
afr_mcu_port(kernel DEPENDS my_board_driver freertos_port)

# If you need to specify additional configurations, use standard CMake functions with
# AFR::kernel::mcu_port as the target name.
target_include_directories(
    AFR::kernel::mcu_port
    INTERFACE
        "${additional_includes}" # e.g. board configuration files
)
target_link_libraries(
    AFR::kernel::mcu_port
    INTERFACE
        "${additional_dependencies}"
)
```

4. To test your list file and configuration, you can write a simple application that uses the FreeRTOS kernel port. For more information about developing and building FreeRTOS applications with CMake, see Building FreeRTOS with CMake (p. 17).
5. After you create the demo, add `add_executable` and `target_link_libraries` calls to the list file, and compile the kernel as a static library to verify that the kernel portable layer is correctly configured.

```
add_executable(
    my_demo
    main.c
)
target_link_libraries(
    my_demo
    PRIVATE AFR::kernel
)
```

Setting up the porting targets for FreeRTOS modules

After you add the portable layer target for the kernel, you can add portable layer targets for other FreeRTOS modules.

For example, to add the portable layer for the Wi-Fi module:

```
afr_mcu_port(wifi)
target_sources(
    AFR::wifi::mcu_port
    INTERFACE "${AFR_MODULES_DIR}/vendors/vendor/boards/board/ports/wifi/iot_wifi.c"
)
```

This example Wi-Fi module portable layer has only one implementation file, which is based on the driver code.

If you want to add the portable layer for the FreeRTOS Secure Sockets module, the module depends on TLS. This makes its portable layer target slightly more complicated than that of the Wi-Fi module. FreeRTOS provides a default TLS implementation based on mbedTLS that you can link to:

```
afr_mcu_port(secure_sockets)
```

```
target_sources(
    AFR::secure_sockets::mcu_port
    INTERFACE ${portable_layer_sources}
)
target_link_libraries(
    AFR::secure_sockets::mcu_port
    AFR::tls
)
```

In this example code, the standard CMake function `target_link_libraries` states that the Secure Sockets portable layer depends on `AFR::tls`.

You can reference all FreeRTOS modules by using their target name `AFR::`*`module_name`*. For example, you can use the same syntax to also state a dependency on FreeRTOS-Plus-TCP:

```
target_link_libraries(
    AFR::secure_sockets::mcu_port
    AFR::freertos_plus_tcp
    AFR::tls
)
```

Note

If your platform handles TLS by itself, you can use your driver code directly. If you use your driver code directly for TLS, you don't need to call `target_link_libraries`, because all FreeRTOS modules implicitly depend on the kernel that includes your driver code.

Because all non-kernel FreeRTOS modules implicitly depend on the kernel, their porting layers don't require you to specify the kernel as a dependency. The POSIX module, however, is defined as an optional kernel module. If you want to use POSIX, you must explicitly include it in your kernel portable layer. For example:

```
# By default, AFR::posix target does not expose standard POSIX headers in its
 public
# interface, i.e., You need to use "freertos_plus_posix/source/
FreeRTOS_POSIX_pthread.c"  instead of "pthread.h".
# Link to AFR::use_posix instead if you need to use those headers directly.
target_link_libraries(
    AFR::kernel::mcu_port
    INTERFACE AFR::use_posix
)
```

FreeRTOS demos and tests

The final section of the template file defines the demo and test targets for FreeRTOS. CMake targets are created automatically for each demo and test that satisfies the dependency requirements.

In this section, define an executable target with the `add_executable` function. Use `aws_tests` as the target name if you're compiling tests, or `aws_demos` if you're compiling demos. You might need to provide other project settings, such as linker scripts and post-build commands. For example:

```
if(AFR_IS_TESTING)
    set(exe_target aws_tests)
else()
    set(exe_target aws_demos)
endif()

set(CMAKE_EXECUTABLE_SUFFIX ".elf")
add_executable(${exe_target} "${board_dir}/application_code/main.c")
```

`target_link_libraries` is then called to link available CMake demo or test targets to your executable target.

Note
You still need to modify `aws_demos/config_files/aws_demo_config.h` and `aws_tests/config_files/aws_test_runner_config.h` to enable demos and tests.

Running post-build commands

For information about running post-build commands, see add_custom_command. Use the second signature. For example:

```
# This should run an external command "command --arg1 --arg2".
add_custom_command(
    TARGET ${exe_target} POST_BUILD COMMAND "command" "--arg1" "--arg2"
)
```

Note
CMake supports many common, platform-independent operations for creating directories, copying files, and so on. For more information about CMake command-line operations, see the CMake command-line tool reference. You can reference the CMake command-line tool from a CMake list file with the built-in variable `${CMAKE_COMMAND}`.

Building FreeRTOS with CMake

CMake targets your host operating system as the target system by default. To use CMake for cross compiling, provide a toolchain file that specifies the compiler that you want to use. You can find some examples in *`freertos`*`/tools/cmake/toolchains`.

If you're using a compiler different from the one provided with FreeRTOS, write this toolchain file before you build FreeRTOS with CMake. You must also set the `CMAKE_TOOLCHAIN_FILE` variable before CMake reads your top-level `CMakeLists.txt` file. The `CMAKE_TOOLCHAIN_FILE` variable specifies which compiler to use and sets some CMake variables, like the system name and the default search path. For more information about cross compiling with CMake, see Cross Compiling on the official CMake wiki.

The `CMakeLists.txt` and toolchain files must be in the correct locations. Before you build FreeRTOS with CMake, make sure that you have set up the FreeRTOS directory structure on your local machine to match the FreeRTOS directory structure on GitHub. See the README.md file for instructions.

To build a CMake-based project

1. Run CMake to generate the build files for a native build system, like Make or Ninja.

   You can use either the CMake command-line tool or the CMake GUI to generate the build files for your native build system.

   For information about generating FreeRTOS build files, see Generating build files (CMake command-line tool) (p. 17) and Generating build files (CMake GUI) (p. 19).
2. Invoke the native build system to make the project into an executable.

   For information about making FreeRTOS build files, see Building FreeRTOS from generated build files (p. 20).

Generating build files (CMake command-line tool)

You can use the CMake command-line tool (`cmake`) to generate FreeRTOS build files from the command line or terminal.

To generate the build files, run `cmake`. For the `DVENDOR` option, specify the vendor. For the `DBOARD` option, specify the board. For the `DCOMPILER` option, specify the compiler. Use the `S` option to specify where your source code is. Use the `B` option to specify where to write the generated files.

> **Note**
> The compiler must be in the system's `PATH` variable, or you must specify the location of the compiler.

For example, if the vendor is Texas Instruments, and the board is the CC3220 Launchpad, and the compiler is GCC for ARM, you can issue the following command to build the source files from the current directory to a directory named *build-directory*:

```
cmake -DVENDOR=ti -DBOARD=cc3220_launchpad -DCOMPILER=arm-ti -S . -B build-directory
```

> **Note**
> If you are using Windows, you must specify the native build system because CMake uses Visual Studio by default. For example:
>
> ```
> cmake -DVENDOR=ti -DBOARD=cc3220_launchpad -DCOMPILER=arm-ti -S . -B build-
> directory -G Ninja
> ```
>
> Or:
>
> ```
> cmake -DVENDOR=ti -DBOARD=cc3220_launchpad -DCOMPILER=arm-ti -S . -B build-
> directory -G "Unix Makefiles"
> ```

The regular expressions `${VENDOR}.*` and `${BOARD}.*` are used to search for a matching board, so you don't have to use the full names of the vendor and board for the `VENDOR` and `BOARD` options. Partial names work, provided there is a single match. For example, the following commands generate the same build files from the same source:

```
cmake -DVENDOR=ti -DCOMPILER=arm-ti -S . -B build-directory
```

```
cmake -DBOARD=cc3220 -DCOMPILER=arm-ti -S . -B build-directory
```

```
cmake -DVENDOR=t -DBOARD=cc -DCOMPILER=arm-ti -S . -B build-directory
```

You can use the `CMAKE_TOOLCHAIN_FILE` option if you want to use a toolchain file that is not located in the default directory `cmake/toolchains`. For example:

```
cmake -DBOARD=cc3220 -DCMAKE_TOOLCHAIN_FILE='/path/to/toolchain_file.cmake' -S . -B build-
directory
```

If the toolchain file does not use absolute paths for your compiler, and you didn't add your compiler to the `PATH` environment variable, CMake might not be able to find it. To make sure that CMake finds your toolchain file, you can use the `AFR_TOOLCHAIN_PATH` option. This option searches the specified toolchain directory path and the toolchain's subfolder under `bin`. For example:

```
cmake -DBOARD=cc3220 -DCMAKE_TOOLCHAIN_FILE='/path/to/toolchain_file.cmake' -
DAFR_TOOLCHAIN_PATH='/path/to/toolchain/' -S . -B build-directory
```

To enable debugging, set the `CMAKE_BUILD_TYPE` to `debug`. With this option enabled, CMake adds debug flags to the compile options, and builds FreeRTOS with debug symbols.

```
# Build with debug symbols
cmake -DBOARD=cc3220 -DCOMPILER=arm-ti -DCMAKE_BUILD_TYPE=debug -S . -B build-directory
```

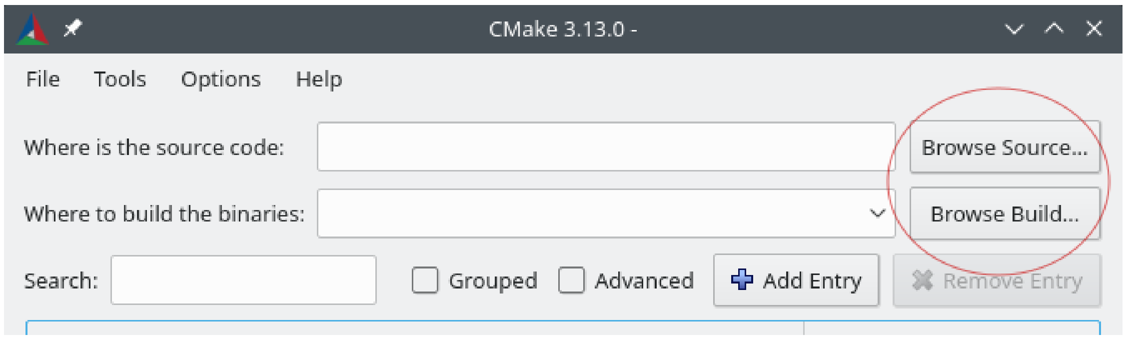
You can also set the `CMAKE_BUILD_TYPE` to `release` to add optimization flags to the compile options.

Generating build files (CMake GUI)

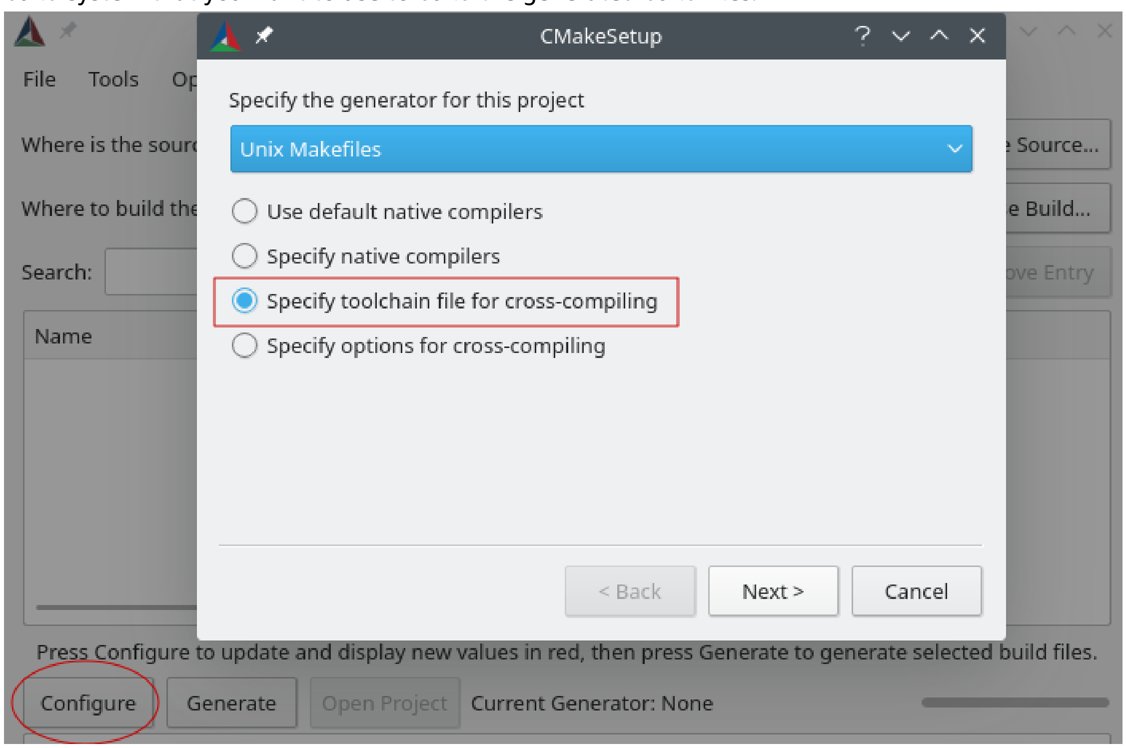
You can use the CMake GUI to generate FreeRTOS build files.

To generate build files with the CMake GUI

1. From the command line, issue `cmake-gui` to start the GUI.
2. Choose **Browse Source** and specify the source input, and then choose **Browse Build** and specify the build output.



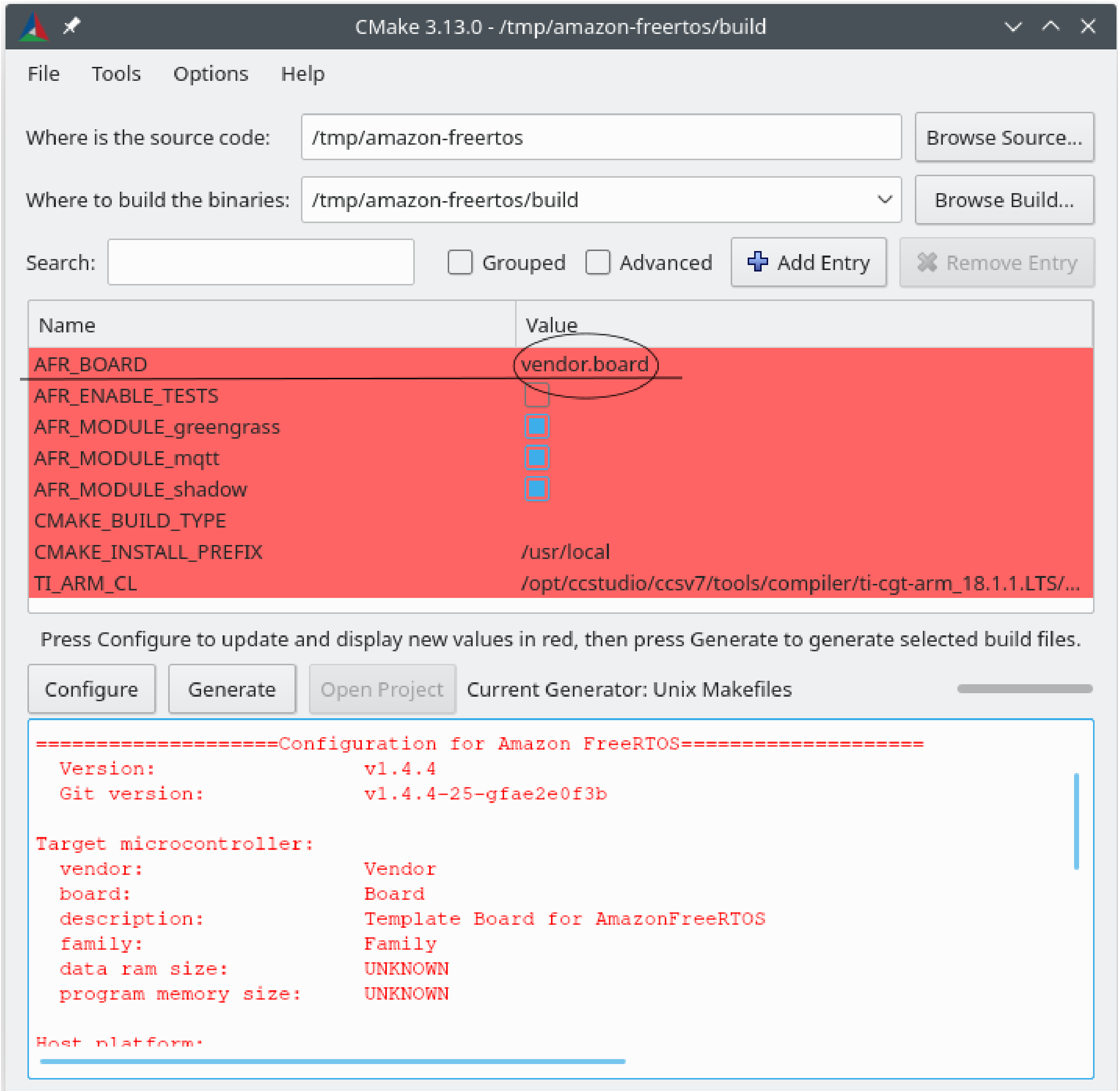
3. Choose **Configure**, and under **Specify the build generator for this project**, find and choose the build system that you want to use to build the generated build files.



4. Choose **Specify toolchain file for cross-compiling**, and then choose **Next**.
5. Choose the toolchain file (for example, `freertos/tools/cmake/toolchains/arm-ti.cmake`), and then choose **Finish**.

   The default configuration for FreeRTOS is the template board, which does not provide any portable layer targets. As a result, a window appears with the message Error in configuration process.

6. The GUI should now look like this:



Choose **AFR_BOARD**, choose your board, and then choose **Configure** again.

7. Choose **Generate**. CMake generates the build system files (for example, makefiles or ninja files), and these files appear in the build directory you specified in the first step. Follow the instructions in the next section to generate the binary image.

Building FreeRTOS from generated build files

You can build FreeRTOS with a native build system by calling the build system command from the output binaries directory. For example, if your build file output directory is `build`, and you are using Make as your native build system, run the following commands:

```
cd build-directory
make -j4
```

You can also use the CMake command-line tool to build FreeRTOS. CMake provides an abstraction layer for calling native build systems. For example:

```
cmake --build build-directory
```

Here are some other common uses of the CMake command-line tool's build mode:

```
# Take advantage of CPU cores.
cmake --build build-directory --parallel 8
```

```
# Build specific targets.
cmake --build build-directory --target afr_kernel
```

```
# Clean first, then build.
cmake --build build-directory --clean-first
```

For more information about the CMake build mode, see the CMake documentation.

Providing an open source license for your code

For qualification, provide an open source license for your ported FreeRTOS code. To determine which license you want to use, see the License and Standards on the Open Source Initiative website.

FreeRTOS Qualification Checklist

Use following checklists to help you keep track of qualification items.

You must pass each of these items in order to be listed in the AWS Partner Device Catalog.

- Review the steps you must follow for Porting FreeRTOS to your device; these are summarized in the FreeRTOS Porting Flowchart. See the FreeRTOS Porting Guide for additional details.
  - You must port a FreeRTOS qualified kernel architecture and cannot make modifications to it on your own. See Configuring a FreeRTOS Kernel Port in the *FreeRTOS Porting Guide* for more information.
- Validate your FreeRTOS port with AWS IoT Device Tester.
  - A complete successful IDT log (with all Test Groups passing on ONE log) is required in your Device Qualification Portal (DQP) submission.
  - All qualification submissions must be made through the Device Listing Portal on APN Partner Central.
- Create a Hello World demo
  - Please refer to Setting up a hello world demo (p. 5).
- Create a Getting Started Guide (GSG) for your device
  - Please refer to Creating a getting started with FreeRTOS guide for your device (p. 7).
- Create an appropriate open source license text file and place it with your code.
  - FreeRTOS is distributed under the MIT license.
- Provide an accessible location to download your code.
  - We recommend you use a github repo, but please do not use a personal GitHub repository. Use an official company GitHub repo.
- Mitigate the following threat in regards to the random number generator (RNG)
  - In order to mitigate the risk of network spoofing and man-in-the-middle attacks that can result in unauthorized data disclosure, a true hardware random number generator (TRNG) is required for FreeRTOS qualification. The TRNG is recommended by the FreeRTOS libraries that implement protocols such as DHCP, DNS, TCP/IP, and TLS. Consistent with the guidance published by NIST, the TRNG on your board is used by FreeRTOS as the entropy source for a standard implementation CTR_DRBG (as described in NIST SP 800-90A - Page50).

    Per the NIST SP 800-90B description, a TRNG is a "physical noise source" (section 2.2.1) that produces "independent and identically distributed" (IID) samples (section 5), for example, a ring oscillator.
  - To control BOM costs and for some customer use cases, certain boards will not have a dedicated TRNG. If you are qualifying these boards, please add the following advisory notice in the header of the file `core_pkcs11.h` that you have ported for the core_pkcs11_pal.h API. Please view our changelog for examples of boards that are similar in this regard.

    Notice: *For best security practice, it is recommended to utilize a random number generation solution that is truly randomized and conforms to the guidelines provided in the FreeRTOS Qualification Checklist. The random number generator method presented in this file by the silicon vendor is not truly random in nature. Please contact the silicon vendor for details regarding the method implemented.*
- If you are qualifying for OTA, verify that you mitigate the risks defined in the OTA Threat Model described in Porting the OTA Library in the *FreeRTOS Porting Guide*.

To be listed in the Online Configuration Wizard, please contact your APN representative and provide the following items.

- Create a CMake list file, and build the test and demo applications with this file.
  - For instructions, see Creating a CMakeLists.txt file for your platform (p. 9).

    Note
    A CMake list file is not required to qualify a board through the AWS Device Qualification Program. The file is only required for listing devices on the FreeRTOS Console.
- Provide the following hardware information for your device.
  - The compiler options for optimizations.
  - The Supported IDE, with latest supported version number.
  - The CLI command to build target executables.
  - The CLI command to flash the target.