



# Intel<sup>®</sup> FPGA SDK for OpenCL

## Getting Started Guide

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Last updated for Intel<sup>®</sup> Quartus<sup>®</sup> Prime Design Suite: 17.0



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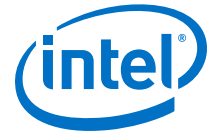
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**A Document Revision History..... 42**



## 1 Intel® FPGA SDK for OpenCL™ Getting Started Guide

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The *Intel® FPGA SDK for OpenCL™ Getting Started Guide* describes the procedures to install the Intel FPGA Software Development Kit (SDK) for OpenCL<sup>1</sup>. This document also contains instructions on how to compile an example OpenCL<sup>2</sup> application with the Intel FPGA SDK for OpenCL.

OpenCL is a C-based open standard for the parallel programming of heterogeneous devices. For more information on the OpenCL Specification version 1.0, refer to the OpenCL Reference Pages. For detailed information on the OpenCL application programming interface (API) and programming language, refer to the *OpenCL Specification version 1.0*.

The Intel FPGA SDK for OpenCL provides a compiler and tools for you to build and run OpenCL applications that target Intel FPGA products. The Intel FPGA SDK for OpenCL supports the embedded profile of the OpenCL Specification version 1.0.

**Attention:** If you only require the Intel FPGA SDK for OpenCL's kernel deployment functionality, download and install the Intel FPGA Runtime Environment (RTE) for OpenCL. Refer to the *Intel FPGA RTE for OpenCL Getting Started Guide* for more information.

Do not install the SDK and the RTE on the same host system.

**Attention:** If you want to use the Intel FPGA SDK for OpenCL with the Cyclone® V SoC Development Kit, refer to the *Intel FPGA SDK for OpenCL Cyclone V SoC Getting Started Guide* for more information.

### Related Links

- [OpenCL Reference Pages](#)
- [OpenCL Specification version 1.0](#)
- [Intel FPGA RTE for OpenCL Getting Started Guide](#)
- [Intel FPGA SDK for OpenCL Cyclone V SoC Getting Started Guide](#)

### 1.1 Prerequisites for the Intel FPGA SDK for OpenCL

To install the Intel FPGA SDK for OpenCL and create an OpenCL application for an Intel preferred accelerator board, your system must meet certain hardware, target platform, and software requirements.

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- 1 The Intel FPGA SDK for OpenCL is based on a published Khronos Specification, and has passed the Khronos Conformance Testing Process. Current conformance status can be found at [www.khronos.org/conformance](http://www.khronos.org/conformance).
  - 2 OpenCL and the OpenCL logo are trademarks of Apple Inc. used by permission of the Khronos Group™.

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## Hardware Requirements

Accelerator boards requirements:

- Acquire a Reference Platform from Intel, or a Custom Platform from an Intel preferred board vendor.

For more information, refer to the Intel FPGA SDK for OpenCL FPGA Platforms page on the Intel FPGA website.

Development system requirements:

- You must have administrator privileges on the development system to install the necessary packages and drivers.
- The development system has at least 85 gigabytes (GB) of free disk space for software installation.
- The development system has at least 24 GB of RAM.  
*Tip:* Refer to board vendor's documentation on the recommended system storage size.
- For PCI Express\* (PCIe\*) accelerator boards, the host machine motherboard must have an available PCIe port slot that is at least the same width (that is, the same number of PCIe lanes) as the board.

The host system must be running one of the following supported operating systems:

- For a list of supported Windows and Linux operating systems, refer to the [Operating System Support](#) page on the Intel FPGA website.

## Software Prerequisites

Develop your host application using one of the following Intel FPGA SDK for OpenCL- and Quartus® Prime software-compatible C compiler or software development environment:

- For Windows systems, use Microsoft Visual Studio version 2010 Professional.
- For Linux systems, use the C compiler included with the GCC.

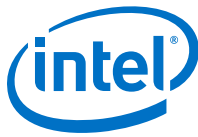
Linux systems require the Perl command version 5 or later. Include the path to the Perl command in your *PATH* system environment variable setting.

## Related Links

[Intel FPGA SDK for OpenCL FPGA Platforms](#)

## 1.2 Contents of the Intel FPGA SDK for OpenCL

The Intel FPGA SDK for OpenCL provides logic components, drivers, and SDK-specific libraries and files.



### Logic Components

- The *Intel FPGA SDK for OpenCL Offline Compiler* translates your OpenCL device code into a hardware configuration file that the system loads onto an Intel FPGA product.
- The *Intel FPGA SDK for OpenCL utility* includes a set of commands you can invoke to perform high-level tasks such as running diagnostic tests.
- The *host runtime* provides the OpenCL host platform API and runtime API for your OpenCL host application.

The host runtime consists of libraries that provide OpenCL APIs, hardware abstractions, and helper libraries.

### Drivers, Libraries and Files

The software installation process installs the Intel FPGA SDK for OpenCL into a directory that you own. The *ALTERAOCLSDKROOT* environment variable references the path to the SDK's installation directory.

**Table 1. Select Contents of the Intel FPGA SDK for OpenCL Installation Directory**

Windows Folder	Linux Directory	Description
bin	bin	User commands in the SDK. Include this directory in your <i>PATH</i> environment variable setting.
board	board	The Intel FPGA SDK for OpenCL Custom Platform Toolkit and Reference Platforms available with the software. <ul style="list-style-type: none"> <li>• The path to the Custom Platform Toolkit is <i>ALTERAOCLSDKROOT/board/custom_platform_toolkit</i></li> <li>• The path to the s5_ref Reference Platform is <i>ALTERAOCLSDKROOT/board/s5_ref</i></li> </ul>
ip	ip	Intellectual property (IP) cores used to compile device kernels.
host	host	Files necessary for compiling and running your host application.
host\include	host/include	OpenCL Specification version 1.0 header files and software interface files necessary for compiling and linking your host application. The <i>host/include/CL</i> subdirectory also includes the C++ header file <i>cl.hpp</i> . The file contains an OpenCL version 1.1 C++ wrapper API. These C++ bindings enable a C++ host program to access the OpenCL runtime APIs using native C++ classes and methods. <i>Important:</i> The OpenCL version 1.1 C++ bindings are compatible with OpenCL Specification versions 1.0 and 1.1. Add this path to the <i>include</i> file search path in your development environment.
host\nwindows64\lib	host/linux64/lib	OpenCL host runtime libraries that provide the OpenCL platform and runtime APIs. These libraries are necessary for linking your host application. To run an OpenCL application on Linux, include this directory in the <i>LD_LIBRARY_PATH</i> environment variable setting.
host\nwindows64\bin	host/linux64/bin	Runtime commands and libraries necessary for running your host application, wherever applicable. For 64-bit Windows system, include this directory in your <i>PATH</i> environment variable setting. For Windows system, this folder contains runtime libraries. For Linux system, this directory contains platform-specific binary for the <i>aocl</i> utility command.
share	share	Architecture-independent support files.



### Example OpenCL Applications

You can download example OpenCL applications from the OpenCL Design Examples page.

### Related Links

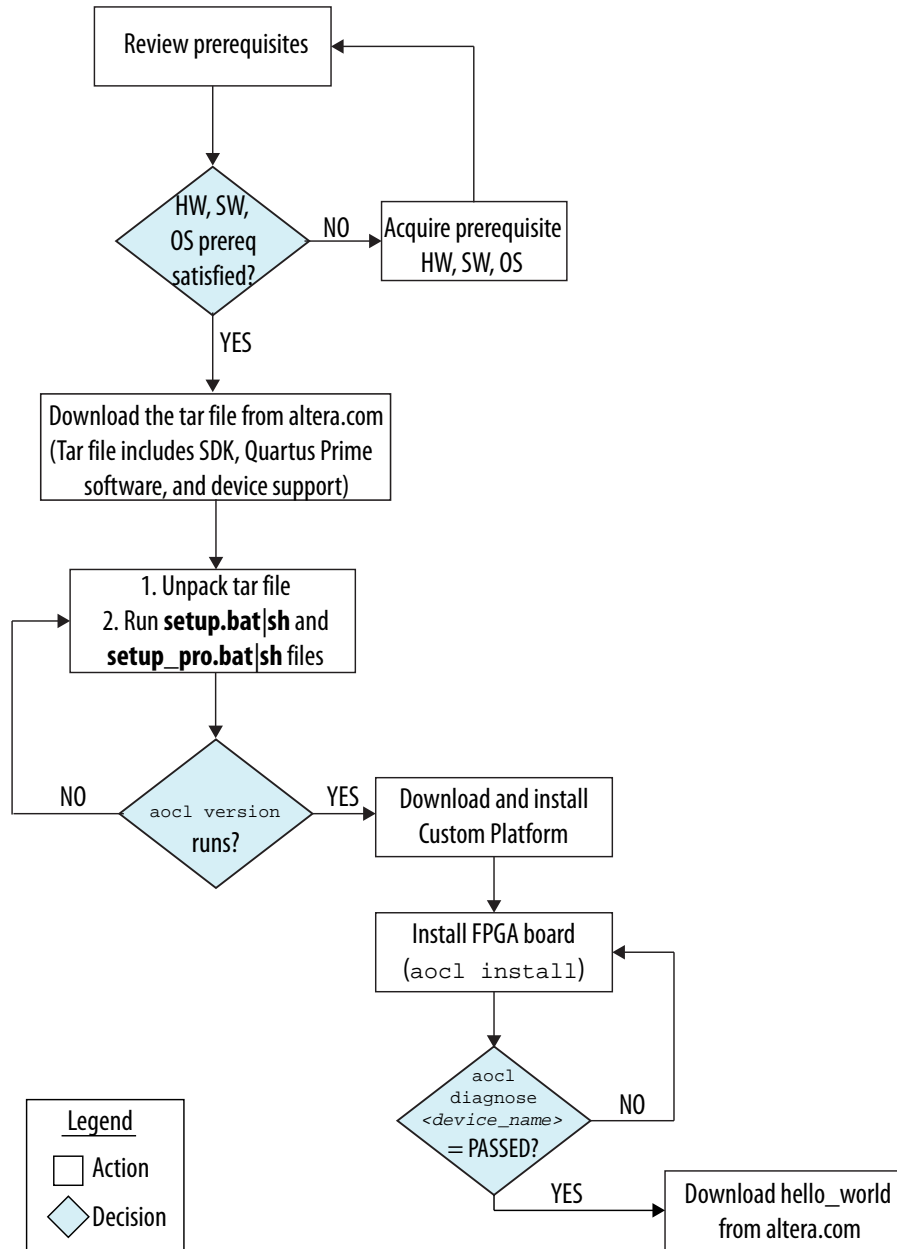
[OpenCL Design Examples](#)

## 1.3 Overview of the Intel FPGA SDK for OpenCL Setup Process

The *Intel FPGA SDK for OpenCL Getting Started Guide* outlines the procedures for installing the Intel FPGA SDK for OpenCL and programming your FPGA.

The figure below summarizes the steps for setting up the necessary software and installing the FPGA board.

Figure 1. Intel FPGA SDK for OpenCL Installation Process Overview



After you complete the initial software and hardware setup successfully, you can create a hardware image from the *hello\_world* OpenCL design example.

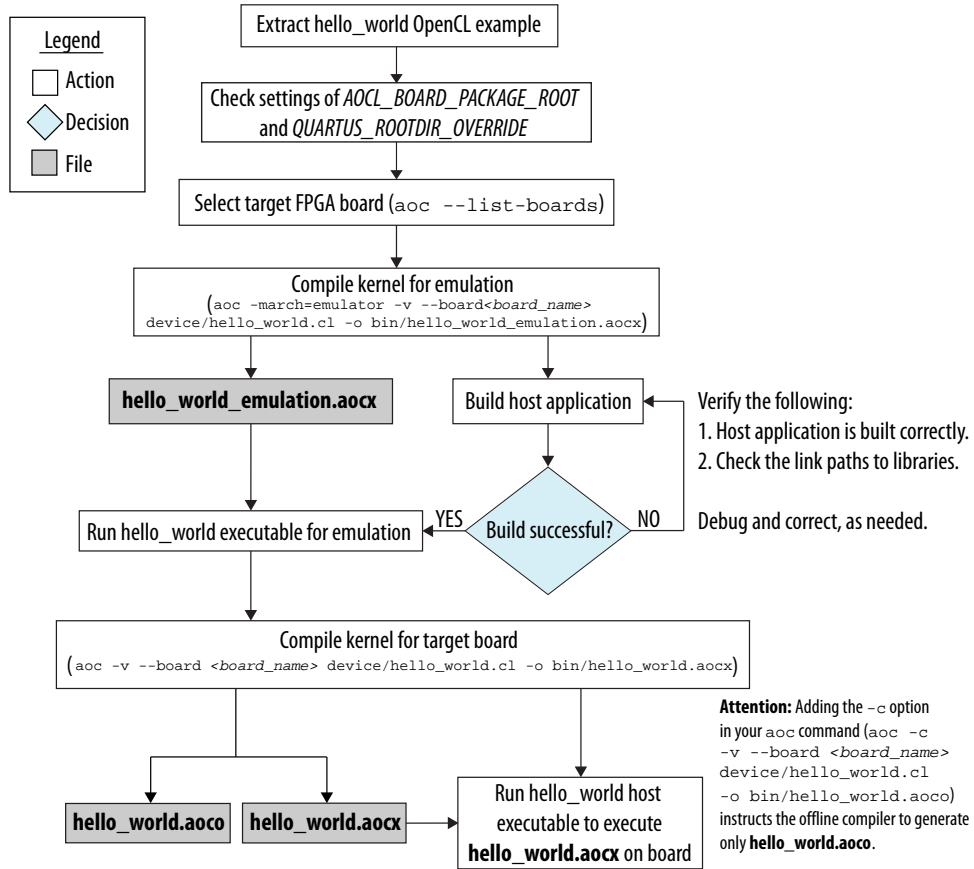
**Important:** Before you program your FPGA with the hardware image, ensure that your FPGA contains an image created using a current version of the Intel FPGA SDK for OpenCL. Refer to *Updating the Hardware Image on the FPGA* for more information

The figure below summarizes the steps you perform to program your FPGA.



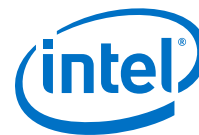


Figure 2. FPGA Programming Overview



**Related Links**

- [Updating the Hardware Image on the FPGA](#) on page 22  
If applicable, before you execute an OpenCL kernel program on the FPGA, ensure that the flash memory of the FPGA contains a hardware image created using a current version of the OpenCL software.
- [Updating the Hardware Image on the FPGA](#)  
If applicable, before you execute an OpenCL kernel program on the FPGA, ensure that the flash memory of the FPGA contains a hardware image created using a current version of the OpenCL software.



## 2 Getting Started with the Intel FPGA SDK for OpenCL for Windows

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The Intel FPGA SDK for OpenCL setup process includes downloading and installing the software, installing the FPGA board, and then executing an OpenCL kernel on the FPGA.

1. [Downloading the Intel FPGA SDK for OpenCL](#) on page 11  
Download the installation package that contains the Intel FPGA SDK for OpenCL and all related software for Windows from the Intel FPGA SDK for OpenCL Download Center.
2. [Installing the Intel FPGA SDK for OpenCL](#) on page 11  
Install the Windows version of the Intel FPGA SDK for OpenCL in a folder that you own.
3. [Setting the Intel FPGA SDK for OpenCL User Environment Variables](#) on page 12  
You have the option to set the Intel FPGA SDK for OpenCL Windows user environment variables permanently or transiently.
4. [Verifying Software Installation](#) on page 13  
Invoke the `version` utility command and verify that the correct version of the OpenCL software is installed.
5. [Licensing the Software](#) on page 14  
Obtain the OpenCL software license from the Self Service Licensing Center.
6. [Installing an FPGA Board](#) on page 15  
To install your board into a Windows host system, invoke the `install` utility command.
7. [Verifying Host Runtime Functionality via Emulation](#) on page 16  
Test the functionality of the host runtime by emulating an OpenCL design example using the Intel FPGA SDK for OpenCL Emulator.
8. [Creating the FPGA Hardware Configuration File of an OpenCL Kernel](#) on page 20  
Compile the `hello_world` kernel program using the Intel FPGA SDK for OpenCL Offline Compiler to create the `hello_world.aocx` executable file.
9. [Updating the Hardware Image on the FPGA](#) on page 22  
If applicable, before you execute an OpenCL kernel program on the FPGA, ensure that the flash memory of the FPGA contains a hardware image created using a current version of the OpenCL software.
10. [Executing an OpenCL Kernel on an FPGA](#) on page 24  
Build your OpenCL host application in Microsoft Visual Studio version 2010 Professional, and run the application by invoking the `hello_world.exe` executable.
11. [Uninstalling the Software](#) on page 25  
To uninstall the Intel FPGA SDK for OpenCL for Windows, run the uninstaller, and restore all modified environment variables to their previous settings.



## 12. Uninstalling the FPGA Board on page 26

To uninstall an FPGA board for Windows, invoke the `uninstall` utility command, uninstall the Custom Platform, and unset the relevant environment variables.

## 2.1 Downloading the Intel FPGA SDK for OpenCL

Download the installation package that contains the Intel FPGA SDK for OpenCL and all related software for Windows from the Intel FPGA SDK for OpenCL Download Center.

The Intel FPGA SDK for OpenCL Download Center provides a tar file that includes all of the following software and files:

- Intel FPGA SDK for OpenCL
  - Quartus Prime Standard Edition software for devices other than Arria® 10 devices
  - Quartus Prime Pro Edition software for Arria 10 devices
  - Device support
1. Go to the Intel FPGA SDK for OpenCL Download Center at the following URL:  
<http://dl.altera.com/openccl/>
  2. Select the software version. The default selection is the current version.
  3. Select **Akamai DLM3 Download Manager** or **Direct Download** as the download method.
  4. Click the **Windows SDK** tab. Click **More** beside **Download and install instructions** to view the download and installation procedure.
  5. Click the download button to start the download process.
  6. Perform the steps outlined in the download and installation instructions on the download page.

### Related Links

[Intel FPGA \(formerly Altera\) website](#)

## 2.2 Installing the Intel FPGA SDK for OpenCL

Unpack the downloaded tar file and run the installation files to install all the software and files.

Install the Windows version of the Intel FPGA SDK for OpenCL in a folder that you own.

You must have administrator privileges.

To install the SDK, Quartus Prime software, and device support files simultaneously, perform the following tasks:

1. Unpack the downloaded `AOCL-<version>-<build>-windows.tar` file into a temporary folder.
2. Run the installers. Intel recommends that you install both editions of the Quartus Prime software.
  - a. Run the `setup.bat` file to install the SDK with the Quartus Prime Standard Edition software.



- b. Run the `setup_pro.bat` file to install the SDK with the Quartus Prime Pro Edition software.
- 3. *Note:* The installer sets the user environment variable `ALTERAOCLSDKROOT` to point to the path of the software installation.

Verify that `ALTERAOCLSDKROOT` points to the current version of the software. Open a Windows command window and then type `echo %ALTERAOCLSDKROOT%` at the command prompt.

If the returned path does not point to the location of the SDK installation, edit the `ALTERAOCLSDKROOT` setting.

For instructions on modifying environment variable settings, refer to *Setting the Intel FPGA SDK for OpenCL User Environment Variables*.

### Related Links

[Setting the Intel FPGA SDK for OpenCL User Environment Variables](#) on page 12  
You have the option to set the Intel FPGA SDK for OpenCL Windows user environment variables permanently or transiently.

## 2.3 Setting the Intel FPGA SDK for OpenCL User Environment Variables

You have the option to set the Intel FPGA SDK for OpenCL Windows user environment variables permanently or transiently. The environment variable settings describe the FPGA board and the host runtime to the software.

**Attention:** If you set the environment variables permanently, you apply the settings once during installation. If you set the environment variables transiently, you must apply the settings during installation and during every subsequent session you run.

**Table 2. Intel FPGA SDK for OpenCL Windows User Environment Variable Settings**

Environment Variable	Path to Include
<code>PATH</code>	<ol style="list-style-type: none"><li>1. <code>%ALTERAOCLSDKROOT%\bin</code></li><li>2. <code>%ALTERAOCLSDKROOT%\windows64\bin</code></li><li>3. <code>%ALTERAOCLSDKROOT%\host\windows64\bin</code></li></ol> where <code>ALTERAOCLSDKROOT</code> points to the path of the software installation



- To apply permanent environment variable settings, perform the following tasks:
  - a. Click **Windows Start menu > Control Panel** (or search for and then open the Control Panel application in Windows 8.1 and Windows 10).
  - b. Click **System and Security > System**.
  - c. In the **System** window, click **Advanced system settings**.
  - d. Click the **Advanced** tab in the **System Properties** dialog box.
  - e. Click **Environment Variables**.  
The **Environment Variables** dialog box appears.
  - f. To modify an existing environment variable setting, select the variable under **User variables for <user\_name>** and then click **Edit**. In the **Edit User Variable** dialog box, type the environment variable setting in the **Variable value** field.
  - g. If you add a new environment variable, click **New** under **User variables for <user\_name>**. In the **New User Variable** dialog box, type the environment variable name and setting in the **Variable name** and **Variable value** fields, respectively.

For an environment variable with multiple settings, add semicolons to separate the settings.

- To apply transient environment variable settings, open a command window and run the `%ALTERAOCLSDKROOT%\init_opencl.bat` script.

Example script output:

```
AOCL_BOARD_PACKAGE_ROOT path is not set in environment
Setting to default s5_ref board.
If you want to target another board, do
  set AOCL_BOARD_PACKAGE_ROOT=board_pkg_dir
and re-run this script
Adding %ALTERAOCLSDKROOT%\bin to PATH
Adding %ALTERAOCLSDKROOT%\host\windows64\bin to PATH
Adding %AOCL_BOARD_PACKAGE_ROOT%\windows64\bin to PATH
```

where `AOCL_BOARD_PACKAGE_ROOT` points to the path of the Custom or Reference Platform.

Running the `init_opencl.bat` script only affects the current command window. The script performs the following tasks:

- Finds the Quartus Prime installation
- Finds the Microsoft Visual Studio installation
- Imports the Microsoft Visual Studio environment to properly set the `LIB` environment variable
- Ensures that the `PATH` environment variable includes the path to the Microsoft `LINK.EXE` file and the `aoc.exe` file

## 2.4 Verifying Software Installation

Invoke the `version` utility command and verify that the correct version of the OpenCL software is installed.



- At a command prompt, invoke the `aocl version` utility command. An output similar to the one below notifies you of a successful installation:

```
aocl <version>.<build> (Intel(R) FPGA SDK for OpenCL(TM), Version <version>
Build <build>, Copyright (C) <year> Intel Corporation)
```

- If installation was unsuccessful, reinstall the software. You can also refer to the *Intel FPGA Software Installation and Licensing* manual and the Intel FPGA (formerly Altera) Knowledge Base for more information.

#### Related Links

- [Intel FPGA Software Installation and Licensing](#)
- [Intel FPGA \(formerly Altera\) Knowledge Base](#)

## 2.5 Licensing the Software

Obtain the OpenCL software license from the Self Service Licensing Center.

The OpenCL software license allows the software to access relevant Quartus Prime software functionality and device support without an additional Quartus Prime software license.

For information on the licensing options and requirements, refer to the *Licensing Intel FPGA Software* section of the *Intel FPGA Software Installation and Licensing* manual, the `LICENSE.txt` file that accompanies each software, and the Intel FPGA Licensing page.

1. Go to the myAltera website at the following URL and log into your account:  
<https://mysupport.altera.com/AlteraLicensing/license/index.html>
2. Click **Self Service Licensing Center**.
3. Perform the steps outlined in the *Using the Self-Service Licensing Center* section of the *Intel FPGA Software Installation and Licensing* manual to obtain and activate the license.
4. If you have a fixed license, append the `<path_to_license_file>/<license_filename>` file to the `LM_LICENSE_FILE` environment variable in the following manner:
  - a. Create a backup copy of the provided license file.
  - b. Save the new license file on your local hard drive.
  - c. Append the `<path_to_license_file>/<license_filename>` file to the `LM_LICENSE_FILE` environment variable.
5. If you have a floating licence, append the `<path_to_license_file>/<license_filename>` file to the `LM_LICENSE_FILE` environment variable in the following manner:
  - a. Obtain the port number and host name from the network or system administrator. Alternatively, the information is in the license file line `SERVER <hostname> <8 to 12 character host or NIC ID> <port>`.  
The license location for the user is `<port>@<hostname>`. If a port is not listed in the license file, specify `@<hostname>`.
  - b. Modify the license file to update the port number and host name.



- c. Append the `<path_to_license_file>/<license_filename>` file to the `LM_LICENSE_FILE` environment variable setting.

### Related Links

- [Intel FPGA Licensing](#)
- [Using the Self-Service Licensing Center](#)
- [Intel FPGA \(formerly Altera\) website](#)
- [Licensing Intel FPGA Software](#)

## 2.6 Installing an FPGA Board

Before creating an OpenCL application for an FPGA board, you must first download and install the Custom Platform from your board vendor. Most Custom Platform installers require administrator privileges. To install your board into a Windows host system, invoke the `install` utility command.

The steps below outline the board installation procedure. Some Custom Platforms require additional installation tasks. Consult your board vendor's documentation for further information on board installation.

1. Follow your board vendor's instructions to connect the FPGA board to your system.
2. Download the Custom Platform for your FPGA board from your board vendor's website. To download an Intel FPGA SDK for OpenCL Reference Platform (for example, the Stratix® V Network Reference Platform (`s5_net`)), refer to the Intel FPGA SDK for OpenCL FPGA Platforms page.
3. Install the Custom Platform in a folder that you own (that is, not a system folder). You can install multiple Custom Platforms simultaneously on the same system. To use the SDK utilities, such as `aocl diagnose` with multiple Custom Platforms, you must set the `AOCL_BOARD_PACKAGE_ROOT` environment variable to point to the location of the Custom Platform subdirectory of the board on which you wish to run the utility. The Custom Platform subdirectory contains the `board_env.xml` file. To run the SDK utilities on a different Custom Platform, you must update the `AOCL_BOARD_PACKAGE_ROOT` environment variable to point to the location of the Custom Platform subdirectory of that specific board.

In a system with multiple Custom Platforms, ensure that the host program uses the FPGA Client Driver (FCD), formerly Altera Client Driver (ACD), to discover the boards rather than linking to the Custom Platforms' memory-mapped device (MMD) libraries directly. As long as FCD is correctly set up for Custom Platform, FCD finds all the installed boards at runtime.

4. *Note:* If you ran the `%ALTERAOCLSDKROOT%\init_opencl.bat` script to set the SDK user environment variables, the script has set `AOCL_BOARD_PACKAGE_ROOT` to point to `%ALTERAOCLSDKROOT%\board\s5_ref`, by default.

Set the user environment variable `AOCL_BOARD_PACKAGE_ROOT` to point to the location of the Custom Platform subfolder containing the `board_env.xml` file.

For example, for `s5_net`, set `AOCL_BOARD_PACKAGE_ROOT` to point to the `<path_to_s5_net>\s5_net` folder.

5. Set the `QUARTUS_ROOTDIR_OVERRIDE` user environment variable to point to the correct Quartus Prime software installation directory.



If you have an Arria 10 device, set `QUARTUS_ROOTDIR_OVERRIDE` to point to the installation directory of the Quartus Prime Pro Edition software. Otherwise, set `QUARTUS_ROOTDIR_OVERRIDE` to point to the installation directory of the Quartus Prime Standard Edition software.

6. Add the paths to the Custom Platform libraries (for example, the memory-mapped (MMD) library) to the `PATH` environment variable setting.

For example, if you use `s5_net`, the Windows `PATH` environment variable setting is `%AOCL_BOARD_PACKAGE_ROOT%\windows64\bin`.

For information on setting user environment variables and running the `init_opencl` script, refer to the *Setting the Intel FPGA SDK for OpenCL User Environment Variables* section.

7. *Remember:* You need administrative rights to install a board. To run a Windows command prompt as an administrator, click **Start > All Programs > Accessories**. Under **Accessories**, right click **Command Prompt**, In the right-click menu, click **Run as Administrator**.

Invoke the command `aocl install` at a command prompt.

Invoking `aocl install` also installs a board driver that allows communication between host applications and hardware kernel programs.

8. To query a list of FPGA devices installed in your machine, invoke the `aocl diagnose` command.

The software generates an output that includes the `<device_name>`, which is an `acl` number that ranges from `acl0` to `acl31`.

For more information on querying the `<device_name>` of your accelerator board, refer to the *Querying the Device Name of Your FPGA Board* section.

9. To verify the successful installation of the FPGA board, invoke the command `aocl diagnose <device_name>` to run any board vendor-recommended diagnostic test.

### Related Links

- [Installing the Cyclone V SoC Development Kit](#)
- [Querying the Device Name of Your FPGA Board](#) on page 22  
When you query a list of accelerator boards, the OpenCL software produces a list of installed devices on your machine in the order of their device names.
- [Intel FPGA SDK for OpenCL FPGA Platforms](#)
- [Setting the Intel FPGA SDK for OpenCL User Environment Variables](#) on page 12  
You have the option to set the Intel FPGA SDK for OpenCL Windows user environment variables permanently or transiently.

## 2.7 Verifying Host Runtime Functionality via Emulation

Test the functionality of the host runtime by emulating an OpenCL design example using the Intel FPGA SDK for OpenCL Emulator.





1. Install a Custom or Reference Platform because emulation targets a specific FPGA board.
  2. Verify that the `AOCL_BOARD_PACKAGE_ROOT` environment variable points to the location of the `board_env.xml` file within the Custom or Reference Platform. Open a Windows command window and then type `echo %AOCL_BOARD_PACKAGE_ROOT%` at the command prompt.
  3. Verify that the `QUARTUS_ROOTDIR_OVERRIDE` environment variable points to the correct edition of the Quartus Prime software. Open a Windows command window and then type `echo %QUARTUS_ROOTDIR_OVERRIDE%` at the command prompt. If the path to the installation folder of the Quartus Prime software is not returned, add it to the `QUARTUS_ROOTDIR_OVERRIDE` setting.
    - For non-Arria 10 devices, `QUARTUS_ROOTDIR_OVERRIDE` points to the installation folder of the Quartus Prime Standard Edition software.
    - For Arria 10 devices, `QUARTUS_ROOTDIR_OVERRIDE` points to the installation folder of the Quartus Prime Pro Edition software.
  4. Add the path to the `LINK.exe` file in Microsoft Visual Studio to the `PATH` user environment variable setting.
  5. Add the path to the Microsoft compilation time libraries in Microsoft Visual Studio to the `LIB` user environment variable setting.
1. [Downloading an OpenCL Design Example](#) on page 17  
The OpenCL Design Examples page contains sample applications of varying complexities that you can download and run on your FPGA.
  2. [Compiling a Kernel for Emulation](#) on page 18  
To compile an OpenCL kernel for emulation, include the `-march=emulator` option in your `aoc` command.
  3. [Building the Host Application](#) on page 18  
The `<path_to_exm_opencl_hello_world_x64_windows_<version>>\hello_world\hello_world.sln` file contains the host solution. After you open this `.sln` file in Microsoft Visual Studio, you can build the OpenCL host application in the `main.cpp` file.
  4. [Emulating Your OpenCL Kernel](#) on page 19  
To emulate your OpenCL kernel, run the emulation `.aocx` file on the platform on which you build your kernel.

### 2.7.1 Downloading an OpenCL Design Example

The OpenCL Design Examples page contains sample applications of varying complexities that you can download and run on your FPGA.

The following instructions are for downloading the Hello World design.

1. In the OpenCL Design Examples page, under Basic Examples, click **Hello World**.
2. In the Hello World Design Example page, under Downloads, click **<version> x64 Windows package (.zip)** to download the compressed file for your platform.
3. Unzip the `exm_opencl_hello_world_x64_windows_<version>.zip` file and save it in a folder that you have write access for.

*Important:* Ensure that the folder name does not contain spaces.



## Related Links

[OpenCL Design Examples](#)

### 2.7.2 Compiling a Kernel for Emulation

To compile an OpenCL kernel for emulation, include the `-march=emulator` option in your `aoc` command.

- To compile the kernel for your target FPGA board, at a command prompt, navigate to the `hello_world` design and then invoke the following command:

```
aoc -march=emulator -v --board <board_name> device/  
hello_world.cl -o bin/hello_world_emulation.aocx
```

The Intel FPGA SDK for OpenCL Offline Compiler compiles the `hello_world.cl` kernel source file and creates the `hello_world_emulation.aocx` emulation-specific executable file in the `bin` subdirectory.

### 2.7.3 Building the Host Application

The `<path_to_exm_openc1_hello_world_x64_windows_<version>>\hello_world\hello_world.sln` file contains the host solution. After you open this `.sln` file in Microsoft Visual Studio, you can build the OpenCL host application in the `main.cpp` file.

If you are using Microsoft Visual Studio 2015, you need the FPGA Client Driver (FCD), formerly Altera Client Driver (ACD), and the Installable Client Driver (ICD) from Khronos. To set up Visual Studio 2015 with FCD and ICD, perform the following tasks prior to building the host application:

- Verify that FCD and ICD are set up correctly. You must set up FCD and ICD manually if invoking the `aocl install` utility command fails to set them up. For instructions, refer to the *Accessing Custom Platform-Specific Functions* and *Linking to the ICD Loader Library on Windows* sections of the *Intel FPGA SDK for OpenCL Programming Guide* for more information.
- Link the host application to the `OpenCL.lib` library.
  - Under the solution properties, select **Configuration Properties > Linker > Input**.
  - In the **Additional Dependencies** field, enter `OpenCL.lib`.

**Attention:** Because you are using FCD and ICD, do not link the host program to `alteracl.lib` or to your Custom Platform's MMD libraries directly.

To build the `hello_world` host application, perform the following tasks:

- Open the `<path_to_exm_openc1_hello_world_x64_windows_<version>>\hello_world\hello_world.sln` file in Microsoft Visual Studio.
- Verify that the build configuration is correct. The default build configuration is **Debug**, but you can use **Release**. You must select the appropriate option as the solution platform (for example, for x64 architecture, select **x64**).
- Build the solution by selecting the **Build > Build Solution** menu option, or by pressing the F7 key.



The `hello_world.exe` executable will be in the  
`<path_to_exm_openc1_hello_world_x64_windows_<version>>`  
`\hello_world\bin` folder.

4. Verify that the build is correct. An output ending with a message similar to the one shown below notifies you of a successful build:

```
1> Build succeeded.
1>
1> Time Elapsed 00:00:03:29
===== Build: 1 succeeded, 0 failed, 0 up-to-date, 0 skipped =====
```

**Attention:** You can ignore the LNK4009: PDB 'vc90.pdb' was not found with... warnings because they have no effect on the build. The compiler might issue this type of warning messages if you have built your Windows libraries using a previous version of Microsoft Visual Studio.

### Related Links

- [Accessing Custom Platform-Specific Functions](#)
- [Linking to the ICD Loader Library on Windows](#)

## 2.7.4 Emulating Your OpenCL Kernel

To emulate your OpenCL kernel, run the emulation `.aocx` file on the platform on which you build your kernel.

To emulate your kernel, perform the following steps:

1. Run the utility command `aocl linkflags` to find out which libraries are necessary for building a host application. The software lists the libraries for both emulation and regular kernel compilation flows.
2. Link your host application to the libraries returned by the `aocl linkflags` utility command.
3. Move the `hello_world_emulation.aocx` file to the current working directory so that the host can locate it easily.
4. To run the host application for emulation, first define the number of emulated devices by invoking the `set CL_CONTEXT_EMULATOR_DEVICE_ALTERA=<number_of_devices>` command and then run the host application. This command specifies the number of identical emulation devices that the Emulator needs to provide.
5. After you run the host application, unset the `CL_CONTEXT_EMULATOR_DEVICE_ALTERA` variable by invoking the `set CL_CONTEXT_EMULATOR_DEVICE_ALTERA=` command.

Each invocation of the emulated kernel creates a shared library copy called `<process_ID>-libkernel.so` in a default temporary directory, where `<process_ID>` is a unique numerical value assigned to each emulation run. You may override the default directory by setting the `TMP` or `TEMP` environment variable on Windows, or setting `TMPDIR` on Linux.



### Related Links

[Running the Host Application](#) on page 24

To execute the OpenCL kernel on the FPGA, run the Windows host application that you built from the `.sln` file.

## 2.8 Creating the FPGA Hardware Configuration File of an OpenCL Kernel

Download the Windows version of the `hello_world` OpenCL design example from the OpenCL Design Examples page. Compile the `hello_world` kernel program using the Intel FPGA SDK for OpenCL Offline Compiler to create the `hello_world.aocx` executable file. The `.aocx` file is the FPGA hardware configuration file.

After you successfully install your FPGA board and emulate your kernel, you can create a `.aocx` file that executes on the device. The steps below describe the process of creating a `.aocx` file from the `hello_world` example design. For more information on the OpenCL design examples, refer to the OpenCL Design Examples page.

1. *Note:* The Intel FPGA SDK for OpenCL Offline Compiler compiles an OpenCL kernel for a target FPGA board. You must install the FPGA board before creating a hardware configuration file. If you have not installed the FPGA board, refer to *Installing an FPGA Board* for more instructions.

Verify that the environment variable `AOCL_BOARD_PACKAGE_ROOT` points to a local subfolder within your Custom Platform that contains the `board_env.xml` file. Open a Windows command window and then type `echo %AOCL_BOARD_PACKAGE_ROOT%` at the command prompt.

If `AOCL_BOARD_PACKAGE_ROOT` is not set, or if the returned path does not point to the Custom Platform for your FPGA board, reset the `AOCL_BOARD_PACKAGE_ROOT` environment variable setting. Refer to *Setting the Intel FPGA SDK for OpenCL User Environment Variables* for more instructions.

2. Verify that the `QUARTUS_ROOTDIR_OVERRIDE` environment variable points to the correct edition of the Quartus Prime software. Open a Windows command window and then type `echo %QUARTUS_ROOTDIR_OVERRIDE%` at the command prompt.

If the path to the installation folder of the Quartus Prime software is not returned, add it to the `QUARTUS_ROOTDIR_OVERRIDE` setting.

- For non-Arria 10 devices, `QUARTUS_ROOTDIR_OVERRIDE` points to the installation folder of the Quartus Prime Standard Edition software.
- For Arria 10 devices, `QUARTUS_ROOTDIR_OVERRIDE` points to the installation folder of the Quartus Prime Pro Edition software.

3. Select your target FPGA board. To list the FPGA boards available in your Custom Platform, invoke the command `aoc --list-boards` at a command prompt.

For more information on the `--list-boards` option of the `aoc` command, refer to the *Listing the Available FPGA Boards in Your Custom Platform (--list-boards)* section of the *Intel FPGA SDK for OpenCL Programming Guide*.

4. At a command prompt, navigate to the `hello_world` design folder containing the `hello_world.cl` file that you used for emulation.
5. To compile the kernel for your target FPGA board, invoke the following command:



```
aoc -v --board <board_name> device/hello_world.cl -o bin/hello_world.aocx
```

This command performs the following tasks:

- Generates the Quartus Prime design project files from the OpenCL source code.
- Checks for initial syntax errors.
- Performs basic optimizations.
- Creates a `hello_world` folder containing necessary intermediate files.
- Creates the *Intel FPGA SDK for OpenCL Offline Compiler Object File* (`.aoco`).
- Creates the `.aocx` file.

**Attention:** The `.aocx` file might take hours to build, depending on the complexity of the kernel. To view the progress of the compilation on-screen, include the `-v` flag in your `aoc` command. An example output is shown below.

```
aoc: Environment checks are completed successfully.
You are now compiling the full flow!!
aoc: Selected target board <board_name>
aoc: Running OpenCL parser...
aoc: OpenCL parser completed successfully.
aoc: Compiling...
aoc: Linking with IP library ...
aoc: First stage compilation completed successfully.
aoc: Setting up project for CvP revision flow...
aoc: Hardware generation completed successfully.
```

The offline compiler displays the line `aoc: Hardware generation completed successfully.` to signify the completion of the compilation process.

For more information on the `--board <board_name>` option of the `aoc` command, refer to the *Compiling a Kernel for a Specific FPGA Board (--board <board\_name>)* section of the *Intel FPGA SDK for OpenCL Programming Guide*.

For more information on the `-v` option of the `aoc` command, refer to the *Generating Compilation Progress Report (-v)* section of the *Intel FPGA SDK for OpenCL Programming Guide*.

For more information on the `-o <filename>` option of the `aoc` command, refer to the *Specifying the Name of an Intel FPGA SDK for OpenCL Offline Compiler Output File (-o <filename>)* section of the *Intel FPGA SDK for OpenCL Programming Guide*.

### Related Links

- [Listing the Available FPGA Boards in Your Custom Platform \(--list-boards\)](#)
- [Compiling a Kernel for a Specific FPGA Board \(--board <board\\_name>\)](#)
- [Generating Compilation Progress Report \(-v\)](#)
- [Specifying the Name of an AOC Output File \(-o <filename>\)](#)
- [OpenCL Design Examples](#)
- [Setting the Intel FPGA SDK for OpenCL User Environment Variables](#) on page 12



You have the option to set the Intel FPGA SDK for OpenCL Windows user environment variables permanently or transiently.

- [Installing an FPGA Board](#) on page 15  
To install your board into a Windows host system, invoke the `install` utility command.

## 2.9 Updating the Hardware Image on the FPGA

If applicable, before you execute an OpenCL kernel program on the FPGA, ensure that the flash memory of the FPGA contains a hardware image created using a current version of the OpenCL software.

**Remember:** If your Custom Platform requires that you preload a valid OpenCL image into the flash memory, for every major release of the Quartus Prime Design Suite, program the flash memory of the FPGA with a hardware image compatible with the current version of the software.

### 2.9.1 Querying the Device Name of Your FPGA Board

Some OpenCL software utility commands require you to specify the device name (`<device_name>`). The `<device_name>` refers to the `acl` number (e.g. `acl0` to `acl31`) that corresponds to the FPGA device. When you query a list of accelerator boards, the OpenCL software produces a list of installed devices on your machine in the order of their device names.

- To query a list of installed devices on your machine, type `aocl diagnose` at a command prompt.  
The software generates an output that resembles the example shown below:

```
aocl diagnose: Running diagnostic from ALTERAOCLSDKROOT/board/<board_name>/
<platform>/libexec

Verified that the kernel mode driver is installed on the host machine.

Using board package from vendor: <board_vendor_name>
Querying information for all supported devices that are installed on the host
machine ...

device_name  Status  Information
acl0         Passed  <descriptive_board_name>
           PCIe dev_id = <device_ID>, bus:slot.func = 02:00.00,
           at Gen 2 with 8 lanes.
           FPGA temperature=43.0 degrees C.

acl1         Passed  <descriptive_board_name>
           PCIe dev_id = <device_ID>, bus:slot.func = 03:00.00,
           at Gen 2 with 8 lanes.
           FPGA temperature = 35.0 degrees C.

Found 2 active device(s) installed on the host machine, to perform a full
diagnostic on a specific device, please run aocl diagnose <device_name>

DIAGNOSTIC_PASSED
```



## 2.9.2 Programming the Flash Memory of an FPGA

Configure the FPGA by loading the hardware image of an Intel FPGA SDK for OpenCL design example into the flash memory of the device. When there is no power, the FPGA retains the hardware configuration file in the flash memory. When you power up the system, it configures the FPGA circuitry based on this hardware image in the flash memory. Therefore, it is imperative that an OpenCL-compatible hardware configuration file is loaded into the flash memory of your FPGA.

Preloading an OpenCL image into the flash memory is necessary for the proper functioning of many Custom Platforms. For example, most PCIe-based boards require a valid OpenCL image in flash memory so that hardware on the board can use the image to configure the FPGA device when the host system powers up for the first time. If the FPGA is not configured with a valid OpenCL image, the system will fail to enumerate the PCIe endpoint, or the driver will not function.

Before running any designs, ensure that the flash memory of your board has a valid OpenCL image that is compatible with the current OpenCL software version. Consult your board vendor's documentation for board-specific requirements.

**Caution:** When you load the hardware configuration file into the flash memory of the FPGA, maintain system power for the entire loading process, which might take a few minutes. Also, do not launch any host code that calls OpenCL kernels or might otherwise communicate with the FPGA board.

To load your hardware configuration file into the flash memory of your FPGA board, perform the following tasks:

1. Install any drivers or utilities that your Custom Platform requires.  
For example, some Custom Platforms require you to install the USB-Blaster™ driver to load your hardware configuration file into the flash memory. For installation instructions, refer to the *USB-Blaster II Download Cable User Guide*.
2. Verify that you set the `AOCL_BOARD_PACKAGE_ROOT` environment variable to point to the subfolder in your Custom Platform that contains the `board_env.xml` file. Open a Windows command window and type `echo %AOCL_BOARD_PACKAGE_ROOT%` at the command prompt.  
If the returned path does not point to the location of the `board_env.xml` file within your Custom Platform, follow the instructions in *Setting the Intel FPGA SDK for OpenCL User Environment Variables* to modify the environment variable setting.
3. Download a design example for your Custom Platform.  
*Remember:* Download design examples from the OpenCL Design Examples page, and extract the example to a location that you have write access for. Ensure that the location name does not contain spaces.
4. To load the hardware configuration file into the flash memory, invoke the `aocl flash <device_name> <design_example_filename>.aocx` command, where `<device_name>` refers to the acl number (e.g. `acl0` to `acl31`) that corresponds to your FPGA device, and `<design_example_filename>.aocx` is the hardware configuration file you create from the `<design_example_filename>.cl` file in the design example package.
5. Power down your device or computer and then power it up again.



Power cycling ensures that the FPGA configuration device retrieves the hardware configuration file from the flash memory and configures it into the FPGA.

**Warning:** Some Custom Platforms require you to power cycle the entire host system after programming the flash memory. For example, PCIe-based Custom Platforms might require a host system reboot to reenumerate the PCIe endpoint. Intel recommends that you power cycle the complete host system after programming the flash memory.

#### Related Links

- [Intel FPGA Download Cable II \(formerly USB-Blaster II Download Cable\) User Guide](#)
- [OpenCL Design Examples](#)
- [Setting the Intel FPGA SDK for OpenCL User Environment Variables](#) on page 12  
You have the option to set the Intel FPGA SDK for OpenCL Windows user environment variables permanently or transiently.

## 2.10 Executing an OpenCL Kernel on an FPGA

Build your OpenCL host application in Microsoft Visual Studio version 2010 Professional, and run the application by invoking the `hello_world.exe` executable. The Intel FPGA SDK for OpenCL is compatible with 64-bit host binaries only.

#### Related Links

[Building the Host Application](#) on page 18

The `<path_to_exm_opencl_hello_world_x64_windows_<version>>\hello_world\hello_world.sln` file contains the host solution. After you open this `.sln` file in Microsoft Visual Studio, you can build the OpenCL host application in the `main.cpp` file.

### 2.10.1 Running the Host Application

To execute the OpenCL kernel on the FPGA, run the Windows host application that you built from the `.sln` file.

1. Add the path `%ALTERAOCLSDKROOT%\host\windows64\bin` to the `PATH` environment variable.
2. At a command prompt, navigate to the host executable within the `<path_to_exm_opencl_hello_world_x64_windows_<version>>\hello_world\bin` folder.
3. Invoke the `hello_world.exe` executable.  
The `hello_world` executable executes the kernel code on the FPGA.

### 2.10.2 Output from Successful Kernel Execution

When you run the host application to execute your OpenCL kernel on the target FPGA, the OpenCL software notifies you of a successful kernel execution.





Example output:

```

Reprogramming device [0] with handle 1
Querying platform for info:
=====
CL_PLATFORM_NAME                = Intel(R) FPGA SDK for OpenCL(TM)
CL_PLATFORM_VENDOR              = Intel Corporation
CL_PLATFORM_VERSION = OpenCL 1.0 Intel(R) FPGA SDK for OpenCL(TM), Version
<version>

Querying device for info:
=====
CL_DEVICE_NAME                  = <board name> : <descriptive board name>
CL_DEVICE_VENDOR                = <board vendor name>
CL_DEVICE_VENDOR_ID             = <board vendor ID>
CL_DEVICE_VERSION = OpenCL 1.0 Intel(R) FPGA SDK for OpenCL(TM), Version
<version>
CL_DRIVER_VERSION               = <version>
CL_DEVICE_ADDRESS_BITS          = 64
CL_DEVICE_AVAILABLE            = true
CL_DEVICE_ENDIAN_LITTLE        = true
CL_DEVICE_GLOBAL_MEM_CACHE_SIZE = 32768
CL_DEVICE_GLOBAL_MEM_CACHELINE_SIZE = 0
CL_DEVICE_GLOBAL_MEM_SIZE       = 8589934592
CL_DEVICE_IMAGE_SUPPORT         = true
CL_DEVICE_LOCAL_MEM_SIZE        = 16384
CL_DEVICE_MAX_CLOCK_FREQUENCY  = 1000
CL_DEVICE_MAX_COMPUTE_UNITS     = 1
CL_DEVICE_MAX_CONSTANT_ARGS     = 8
CL_DEVICE_MAX_CONSTANT_BUFFER_SIZE = 2147483648
CL_DEVICE_MAX_WORK_ITEM_DIMENSIONS = 3
CL_DEVICE_MEM_BASE_ADDR_ALIGN   = 8192
CL_DEVICE_MIN_DATA_TYPE_ALIGN_SIZE = 1024
CL_DEVICE_PREFERRED_VECTOR_WIDTH_CHAR = 4
CL_DEVICE_PREFERRED_VECTOR_WIDTH_SHORT = 2
CL_DEVICE_PREFERRED_VECTOR_WIDTH_INT = 1
CL_DEVICE_PREFERRED_VECTOR_WIDTH_LONG = 1
CL_DEVICE_PREFERRED_VECTOR_WIDTH_FLOAT = 1
CL_DEVICE_PREFERRED_VECTOR_WIDTH_DOUBLE = 0
Command queue out of order?     = false
Command queue profiling enabled? = true
Using AOCX: hello_world.aocx

Kernel initialization is complete.
Launching the kernel...

Thread #2: Hello from the Intel(R) FPGA OpenCL(TM) compiler!

Kernel execution is complete.

```

## 2.11 Uninstalling the Software

To uninstall the Intel FPGA SDK for OpenCL for Windows, run the uninstaller, and restore all modified environment variables to their previous settings.

1. From the Windows Start Menu shortcut, navigate to the installation folder for the Quartus Prime Design Suite.
2. Select **Uninstall Quartus Prime Standard Edition**.  
The uninstallation wizard appears.
3. In the uninstallation wizard, perform the following tasks:
  - a. Select **Individual components** and then click **Next**.
  - b. Select the SDK and then click **Next**.



The uninstaller uninstalls the Intel FPGA SDK for OpenCL.

4. To uninstall the Intel FPGA SDK for OpenCL associated with the Quartus Prime Pro Edition software, select **Uninstall Quartus Prime Pro Edition** from the Altera *<version> Pro Edition* folder to open the uninstallation wizard.
  - a. Repeat 3 on page 25.
5. Remove the following paths from the *PATH* environment variable:
  - a. `%ALTERAOCLSDKROOT%\bin`
  - b. `%ALTERAOCLSDKROOT%\host\windows64\bin`
6. Remove the *ALTERAOCLSDKROOT* environment variable.
7. Remove the *QUARTUS\_ROOTDIR\_OVERRIDE* environment variable.

## 2.12 Uninstalling the FPGA Board

To uninstall an FPGA board for Windows, invoke the `uninstall` utility command, uninstall the Custom Platform, and unset the relevant environment variables. You must uninstall the existing FPGA board if you migrate your OpenCL application to another FPGA board that belongs to a different Custom Platform.

To uninstall your FPGA board, perform the following tasks:

1. Following your board vendor's instructions to disconnect the board from your machine.
2. Invoke the `aocl uninstall` utility command to remove the current host computer drivers (for example, PCIe drivers). The Intel FPGA SDK for OpenCL uses these drivers to communicate with the FPGA board.
3. Uninstall the Custom Platform.
4. Unset the *PATH* environment variable.
5. Unset the *AOCL\_BOARD\_PACKAGE\_ROOT* environment variable.



## 3 Getting Started with the Intel FPGA SDK for OpenCL for Linux

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The Intel FPGA SDK for OpenCL setup process includes downloading and installing the software, installing the FPGA board, and then executing an OpenCL kernel on the FPGA.

1. [Downloading the Intel FPGA SDK for OpenCL](#) on page 28  
Download the installation package that contains the Intel FPGA SDK for OpenCL and all related software for Linux from the Download Center.
2. [Installing the Intel FPGA SDK for OpenCL](#) on page 28  
Install the Linux version of the Intel FPGA SDK for OpenCL in a directory that you own.
3. [Setting the Intel FPGA SDK for OpenCL User Environment Variables](#) on page 29  
You have the option to set the Intel FPGA SDK for OpenCL Linux user environment variables permanently or transiently.
4. [Verifying Software Installation](#) on page 13  
Invoke the `version` utility command and verify that the correct version of the OpenCL software is installed.
5. [Licensing the Software](#) on page 14  
Obtain the OpenCL software license from the Self Service Licensing Center.
6. [Installing an FPGA Board](#) on page 31  
To install your board into a Linux host system, invoke the `install` utility command.
7. [Verifying Host Runtime Functionality via Emulation](#) on page 33  
Test the functionality of the host runtime by emulating an OpenCL design example using the Intel FPGA SDK for OpenCL Emulator.
8. [Creating the FPGA Hardware Configuration File of an OpenCL Kernel](#) on page 35  
Compile the `hello_world` kernel program using the Intel FPGA SDK for OpenCL Offline Compiler to create the `hello_world.aocx` executable file.
9. [Updating the Hardware Image on the FPGA](#) on page 22  
If applicable, before you execute an OpenCL kernel program on the FPGA, ensure that the flash memory of the FPGA contains a hardware image created using a current version of the OpenCL software.
10. [Executing an OpenCL Kernel on an FPGA](#) on page 39  
You must build your OpenCL host application with the `Makefile` file, and run the application by invoking the `hello_world` executable.
11. [Uninstalling the Software](#) on page 41  
To uninstall the Intel FPGA SDK for OpenCL for Linux, remove the software package via the GUI uninstaller, then delete the software directory and restore all modified environment variables to their previous settings.
12. [Uninstalling the FPGA Board](#) on page 41



To uninstall an FPGA board for Linux, invoke the `uninstall` utility command, uninstall the Custom Platform, and unset the relevant environment variables.

### 3.1 Downloading the Intel FPGA SDK for OpenCL

Download the installation package that contains the Intel FPGA SDK for OpenCL and all related software for Linux from the Download Center.

The Download Center provides a tar file that includes all of the following software and files:

- Intel FPGA SDK for OpenCL
  - Quartus Prime Standard Edition software for devices other than Arria 10 devices
  - Quartus Prime Pro Edition software for Arria 10 devices
  - Device support
1. Go to the Intel FPGA SDK for OpenCL Download Center at the following URL:  
<http://dl.altera.com/opencl/>
  2. Select the software version. The default selection is the current version.
  3. Select **Direct Download** as the download method.
  4. Click the **Linux SDK** tab and then click **More** beside **Download and install instructions** to view the download and installation procedure.
  5. Select **Intel FPGA Runtime Environment for OpenCL Linux x86-64 RPM**.
  6. Click the download button to start the download process.
  7. Perform the steps outlined in the download and installation instructions on the download page.

#### Related Links

[Intel FPGA \(formerly Altera\) website](#)

### 3.2 Installing the Intel FPGA SDK for OpenCL

Unpack the downloaded tar file and run the installation files to install all the software and files.

Install the Linux version of the Intel FPGA SDK for OpenCL in a directory that you own.

1. You must have `sudo` or `root` privileges.
2. You must install the Linux OS kernel source and headers (for example, `kernel-devel.x86_64` and `kernel-headers.x86_64`), and the GNU Compiler Collection (GCC) (`gcc.x86_64`).

**Attention:** If you install the software on a system that does not contain any C Shell Run Commands file (`.cshrc`) or Bash Run Commands file (`.bashrc`) in your directory, you must set the environment variables `ALTERAOCLSDKROOT` and `PATH` manually. Alternatively, you may create the `.cshrc` and `.bashrc` files, and then append the environment variables to them. To ensure that the updates take effect, restart your terminal after you set the environment variables.



To install the Intel FPGA SDK for OpenCL, Quartus Prime software, and device support files simultaneously, perform the following tasks:

1. Unpack the downloaded tar file into a temporary directory.
2. Run the installers. Intel recommends that you install both editions of the Quartus Prime software.
  - a. Run the `setup.sh` file to install the SDK with the Quartus Prime Standard Edition software.
  - b. Run the `setup_pro.sh` file to install the SDK with the Quartus Prime Pro Edition software.
3. *Note:* The installer sets the environment variable `ALTERAOCLSDKROOT` to point to the path of the software installation.

Verify that `ALTERAOCLSDKROOT` points to the current version of the software.

Open a shell and then type `echo $ALTERAOCLSDKROOT` at the command prompt.

If the returned path does not point to the location of the Intel FPGA SDK for OpenCL installation, edit the `ALTERAOCLSDKROOT` setting.

For instructions on modifying environment variable settings, refer to *Setting the Intel FPGA SDK for OpenCL User Environment Variables*.

#### Related Links

[Setting the Intel FPGA SDK for OpenCL User Environment Variables](#) on page 29

You have the option to set the Intel FPGA SDK for OpenCL Linux user environment variables permanently or transiently.

## 3.3 Setting the Intel FPGA SDK for OpenCL User Environment Variables

You have the option to set the Intel FPGA SDK for OpenCL Linux user environment variables permanently or transiently. The environment variable settings describe the FPGA board and the host runtime to the software.

**Attention:** If you set the environment variables permanently, you apply the settings once during installation. If you set the environment variables transiently, you must apply the settings during installation and during every subsequent session you run.

**Table 3. Intel FPGA SDK for OpenCL Linux User Environment Variable Settings**

Environment Variable	Path to Include
<code>PATH</code>	<code>\$ALTERAOCLSDKROOT/bin</code> where <code>ALTERAOCLSDKROOT</code> points to the path of the software installation
<code>LD_LIBRARY_PATH</code>	<code>\$ALTERAOCLSDKROOT/host/linux64/lib</code> <code>\$AOCL_BOARD_PACKAGE_ROOT/linux64/lib</code> where <code>AOCL_BOARD_PACKAGE_ROOT</code> points to the path of the Custom or Reference Platform



- To apply permanent environment variable settings, open a shell and then type the `export <variable_name>=<variable_setting>: ${<variable_name>}` command.

For example, the command `export PATH="$ALTEAOCLSDKROOT/bin":$PATH` adds `$ALTEAOCLSDKROOT/bin` to the list of `PATH` settings.

- To apply transient environment variable settings, open a bash-shell command-line terminal and run the `source $ALTEAOCLSDKROOT/init_opencl.sh` command. This command does not work in other shells.

Example script output:

```
AOCL_BOARD_PACKAGE_ROOT path is not set in environment
Setting to default s5_ref board.
If you want to target another board, do
  set AOCL_BOARD_PACKAGE_ROOT=board_pkg_dir
Adding $ALTEAOCLSDKROOT/bin to PATH
Adding $ALTEAOCLSDKROOT/host/linux64/lib to LD_LIBRARY_PATH
Adding $AOCL_BOARD_PACKAGE_ROOT/linux64/lib to LD_LIBRARY_PATH
```

## 3.4 Verifying Software Installation

Invoke the `version` utility command and verify that the correct version of the OpenCL software is installed.

- At a command prompt, invoke the `aocl version` utility command. An output similar to the one below notifies you of a successful installation:

```
aocl <version>.<build> (Intel(R) FPGA SDK for OpenCL(TM), Version <version>
Build <build>, Copyright (C) <year> Intel Corporation)
```

- If installation was unsuccessful, reinstall the software. You can also refer to the *Intel FPGA Software Installation and Licensing* manual and the Intel FPGA (formerly Altera) Knowledge Base for more information.

### Related Links

- [Intel FPGA Software Installation and Licensing](#)
- [Intel FPGA \(formerly Altera\) Knowledge Base](#)

## 3.5 Licensing the Software

Obtain the OpenCL software license from the Self Service Licensing Center.

The OpenCL software license allows the software to access relevant Quartus Prime software functionality and device support without an additional Quartus Prime software license.

For information on the licensing options and requirements, refer to the *Licensing Intel FPGA Software* section of the *Intel FPGA Software Installation and Licensing* manual, the `LICENSE.txt` file that accompanies each software, and the Intel FPGA Licensing page.

1. Go to the myAltera website at the following URL and log into your account:



<https://mysupport.altera.com/AlteraLicensing/license/index.html>

2. Click **Self Service Licensing Center**.
3. Perform the steps outlined in the *Using the Self-Service Licensing Center* section of the *Intel FPGA Software Installation and Licensing* manual to obtain and activate the license.
4. If you have a fixed license, append the `<path_to_license_file>/<license_filename>` file to the `LM_LICENSE_FILE` environment variable in the following manner:
  - a. Create a backup copy of the provided license file.
  - b. Save the new license file on your local hard drive.
  - c. Append the `<path_to_license_file>/<license_filename>` file to the `LM_LICENSE_FILE` environment variable.
5. If you have a floating licence, append the `<path_to_license_file>/<license_filename>` file to the `LM_LICENSE_FILE` environment variable in the following manner:
  - a. Obtain the port number and host name from the network or system administrator. Alternatively, the information is in the license file line `SERVER <hostname> <8 to 12 character host or NIC ID> <port>`.  
The license location for the user is `<port>@<hostname>`. If a port is not listed in the license file, specify `@<hostname>`.
  - b. Modify the license file to update the port number and host name.
  - c. Append the `<path_to_license_file>/<license_filename>` file to the `LM_LICENSE_FILE` environment variable setting.

#### Related Links

- [Intel FPGA Licensing](#)
- [Using the Self-Service Licensing Center](#)
- [Intel FPGA \(formerly Altera\) website](#)
- [Licensing Intel FPGA Software](#)

## 3.6 Installing an FPGA Board

Before creating an OpenCL application for an FPGA board on Linux, you must first download and install the Custom Platform from your board vendor. Most Custom Platform installers require administrator privileges. To install your board into a Linux host system, invoke the `install` utility command.

The steps below outline the board installation procedure. Some Custom Platforms require additional installation tasks. Consult your board vendor's documentation for further information on board installation.



1. Follow your board vendor's instructions to connect the FPGA board to your system.
2. Download the Custom Platform for your FPGA board from your board vendor's website. To download an Intel FPGA SDK for OpenCL Reference Platform (for example, the Stratix V Network Reference Platform), refer to the Intel FPGA SDK for OpenCL FPGA Platforms page.
3. Install the Custom Platform in a directory that you own (that is, not a system directory).

You can install multiple Custom Platforms simultaneously on the same system. To use the SDK utilities, such as `aocl diagnose` with multiple Custom Platforms, you must set the `AOCL_BOARD_PACKAGE_ROOT` environment variable to point to the location of the Custom Platform subdirectory of the board on which you wish to run the utility. The Custom Platform subdirectory contains the `board_env.xml` file. To run the SDK utilities on a different Custom Platform, you must update the `AOCL_BOARD_PACKAGE_ROOT` environment variable to point to the location of the Custom Platform subdirectory of that specific board.

In a system with multiple Custom Platforms, ensure that the host program uses the FPGA Client Drivers (FCD), formerly Altera Client Driver (ACD), to discover the boards rather than linking to the Custom Platforms' memory-mapped device (MMD) libraries directly. As long as FCD is correctly set up for Custom Platform, FCD finds all the installed boards at runtime.

4. *Note:* If you ran the `$ALTERAOCLSDKROOT/init_opencl.sh` script to set the SDK user environment variables, the script has set `AOCL_BOARD_PACKAGE_ROOT` to point to `$ALTERAOCLSDKROOT/board/s5_ref`, by default.

Set the user environment variable `AOCL_BOARD_PACKAGE_ROOT` to point to the location of the Custom Platform subdirectory containing the `board_env.xml` file.

For example, for `s5_net`, set `AOCL_BOARD_PACKAGE_ROOT` to point to the `<path_to_s5_net>/s5_net` directory.

5. Set the `QUARTUS_ROOTDIR_OVERRIDE` user environment variable to point to the correct Quartus Prime software installation directory. Open a shell and then type `echo $QUARTUS_ROOTDIR_OVERRIDE` at the command prompt.

If you have an Arria 10 device, set `QUARTUS_ROOTDIR_OVERRIDE` to point to the installation directory of the Quartus Prime Pro Edition software. Otherwise, set `QUARTUS_ROOTDIR_OVERRIDE` to point to the installation directory of the Quartus Prime Standard Edition software.

6. Add the paths to the Custom Platform libraries (for example, memory-mapped (MMD) library) to the `LD_LIBRARY_PATH` environment variable setting.

For example, if you use `s5_net`, the Linux `LD_LIBRARY_PATH` setting is `$AOCL_BOARD_PACKAGE_ROOT/linux64/lib`.

For information on setting Linux user environment variables and running the `init_opencl` script, refer to the *Setting the Intel FPGA SDK for OpenCL User Environment Variables* section.

7. *Remember:* You need `sudo` or `root` privileges to install a board.

Invoke the command `aocl install` at a command prompt.





Invoking `aocl install` also installs a board driver that allows communication between host applications and hardware kernel programs.

8. To query a list of FPGA devices installed in your machine, invoke the `aocl diagnose` command.

The software generates an output that includes the `<device_name>`, which is an `acl` number that ranges from `acl0` to `acl31`.

For more information on querying the `<device_name>` of your accelerator board, refer to the *Querying the Device Name of Your FPGA Board* section.

9. To verify the successful installation of the FPGA board, invoke the command `aocl diagnose <device_name>` to run any board vendor-recommended diagnostic test.

### 3.7 Verifying Host Runtime Functionality via Emulation

Test the functionality of the host runtime by emulating an OpenCL design example using the Intel FPGA SDK for OpenCL Emulator.

1. Install a Custom or Reference Platform because emulation targets a specific FPGA board.
2. Verify that the `AOCL_BOARD_PACKAGE_ROOT` environment variable points to the location of the `board_env.xml` file within the non-SoC FPGA Custom or Reference Platform. Open a shell and then type `echo $AOCL_BOARD_PACKAGE_ROOT` at the command prompt.
3. Verify that the `QUARTUS_ROOTDIR_OVERRIDE` environment variable points to the correct edition of the Quartus Prime software. Open a shell and then type `echo $QUARTUS_ROOTDIR_OVERRIDE` at the command prompt.

If the path to the installation directory of the Quartus Prime software is not returned, add it to the `QUARTUS_ROOTDIR_OVERRIDE` setting.

- For non-Arria 10 devices, `QUARTUS_ROOTDIR_OVERRIDE` points to the installation folder of the Quartus Prime Standard Edition software.
- For Arria 10 devices, `QUARTUS_ROOTDIR_OVERRIDE` points to the installation folder of the Quartus Prime Pro Edition software.

4. Verify that the `LD_LIBRARY_PATH` environment variable setting includes the paths identified in *Setting the Intel FPGA SDK for OpenCL User Environment Variables*. Open a shell and then type `echo $LD_LIBRARY_PATH` at the command prompt.

If the returned paths do not include `$ALTERAOCLSDKROOT/host/linux64/lib` and `$AOCL_BOARD_PACKAGE_ROOT/linux64/lib`, add them to the `LD_LIBRARY_PATH` setting.

Each invocation of the emulated kernel creates a shared library copy called `<process_ID>-libkernel.so` in a default temporary directory, where `<process_ID>` is a unique numerical value assigned to each emulation run. You may override the default directory by setting the `TMPDIR` environment variable.

1. [Downloading an OpenCL Design Example](#) on page 34  
The OpenCL Design Examples page contains sample applications of varying complexities that you can download and run on your FPGA.
2. [Compiling a Kernel for Emulation](#) on page 34



To compile an OpenCL kernel for emulation, include the `-march=emulator` option in your `aoc` command.

3. [Building the Host Application](#) on page 34  
Build the host executable with the `<path_to_exm_opencl_hello_world_x64_linux_<version>>/hello_world/Makefile` file.
4. [Emulating Your OpenCL Kernel](#) on page 35  
To emulate your OpenCL kernel, run the emulation `.aocx` file on the platform on which you build your kernel.

### 3.7.1 Downloading an OpenCL Design Example

The OpenCL Design Examples page contains sample applications of varying complexities that you can download and run on your FPGA.

The following instructions are for downloading the Hello World design.

1. In the OpenCL Design Examples page, under Basic Examples, click **Hello World**.
2. In the Hello World Design Example page, under Downloads, click **<version> x64 Linux package (.tgz)** to download the compressed file for your platform.
3. Unpack the `.tgz` file and save it in a directory to which you have write access.  
*Important:* Ensure that the directory name does not contain spaces.

#### Related Links

[OpenCL Design Examples](#)

### 3.7.2 Compiling a Kernel for Emulation

To compile an OpenCL kernel for emulation, include the `-march=emulator` option in your `aoc` command.

- To compile the kernel for your target FPGA board, at a command prompt, navigate to the `hello_world` design and then invoke the following command:

```
aoc -march=emulator -v --board <board_name> device/  
hello_world.cl -o bin/hello_world_emulation.aocx
```

This compiles the `hello_world.cl` kernel source file and creates the `hello_world_emulation.aocx` emulation-specific executable file in the `bin` subdirectory.

### 3.7.3 Building the Host Application

Build the host executable with the `<path_to_exm_opencl_hello_world_x64_linux_<version>>/hello_world/Makefile` file.

To build the host application, perform the following tasks:

1. Navigate to the `hello_world` directory.
2. Invoke the `$ make -f Makefile` command. Alternatively, you can simply invoke the `make` command.



The `hello_world` executable will be in the  
`<path_to_exm_openc1_hello_world_x64_linux_<version>>/`  
`hello_world/bin` directory.

### 3.7.4 Emulating Your OpenCL Kernel

To emulate your OpenCL kernel, run the emulation `.aocx` file on the platform on which you build your kernel.

To emulate your kernel, perform the following steps:

1. Run the utility command `aocl linkflags` to find out which libraries are necessary for building a host application. The software lists the libraries for both emulation and regular kernel compilation flows.
2. Link your host application to the libraries returned by the `aocl linkflags` utility command.
3. Move the `hello_world_emulation.aocx` file to the current working directory so that the host can locate it easily.
4. To run the host application for emulation, invoke the `env`  
`CL_CONTEXT_EMULATOR_DEVICE_ALTERA=<number_of_devices>`  
`<host_application_filename>` command.  
 This command specifies the number of identical emulation devices that the Emulator needs to provide.

Each invocation of the emulated kernel creates a shared library copy called `<process_ID>-libkernel.so` in a default temporary directory, where `<process_ID>` is a unique numerical value assigned to each emulation run. You may override the default directory by setting the `TMP` or `TEMP` environment variable on Windows, or setting `TMPDIR` on Linux.

#### Related Links

[Running the Host Application](#) on page 40

To execute the OpenCL kernel on the FPGA, run the Linux host application that you built from the `Makefile`.

## 3.8 Creating the FPGA Hardware Configuration File of an OpenCL Kernel

Download the Linux version of the `hello_world` OpenCL design example from the OpenCL Design Examples page. Compile the `hello_world` kernel program using the Intel FPGA SDK for OpenCL Offline Compiler to create the `hello_world.aocx` executable file. The `.aocx` file is the FPGA hardware configuration file.

After you successfully install your FPGA board and emulate your kernel, you can create a `.aocx` file that executes on the device. The steps below describe the process of creating a `.aocx` file from the `hello_world` example design. For more information on the OpenCL design examples, refer to the OpenCL Design Examples page.

1. *Note:* The Intel FPGA SDK for OpenCL Offline Compiler compiles an OpenCL kernel for a target FPGA board. You must install the FPGA board before creating a hardware configuration file. If you have not installed the FPGA board, refer to *Installing an FPGA Board* for more instructions.



Verify that the environment variable `AOCL_BOARD_PACKAGE_ROOT` points to a local subdirectory within your Custom Platform that contains the `board_env.xml` file. Open a shell and then type `echo $AOCL_BOARD_PACKAGE_ROOT` at the command prompt.

If `AOCL_BOARD_PACKAGE_ROOT` is not set, or if the returned path does not point to the Custom Platform for your FPGA board, reset the `AOCL_BOARD_PACKAGE_ROOT` environment variable setting. Refer to *Setting the Intel FPGA SDK for OpenCL User Environment Variables* for more instructions.

2. Verify that the `QUARTUS_ROOTDIR_OVERRIDE` environment variable points to the correct edition of the Quartus Prime software. Open a shell and then type `echo $QUARTUS_ROOTDIR_OVERRIDE` at the command prompt.

If the path to the installation directory of the Quartus Prime software is not returned, add it to the `QUARTUS_ROOTDIR_OVERRIDE` setting.

- For non-Arria 10 devices, `QUARTUS_ROOTDIR_OVERRIDE` points to the installation folder of the Quartus Prime Standard Edition software.
- For Arria 10 devices, `QUARTUS_ROOTDIR_OVERRIDE` points to the installation folder of the Quartus Prime Pro Edition software.

3. Select your target FPGA board. To list the FPGA boards available in your Custom Platform, invoke the command `aoc --list-boards` at a command prompt.

For more information on the `--list-boards` option of the `aoc` command, refer to the *Listing the Available FPGA Boards in Your Custom Platform (--list-boards)* section of the *Intel FPGA SDK for OpenCL Programming Guide*.

4. At a command prompt, navigate to the `hello_world` design directory containing the `hello_world.cl` file that you used for emulation.
5. To compile the kernel for your target FPGA board, invoke the following command:

```
aoc -v --board <board_name> device/hello_world.cl -o bin/hello_world.aocx
```

This command performs the following tasks:

- Generates the Quartus Prime design project files from the OpenCL source code.
- Checks for initial syntax errors.
- Performs basic optimizations.
- Creates a `hello_world` directory containing necessary intermediate files.
- Creates the *Intel FPGA SDK for OpenCL Offline Compiler Object File* (`.aoco`).
- Creates the `.aocx` file.



**Attention:** The `.aocx` file might take hours to build, depending on the complexity of the kernel. To view the progress of the compilation on-screen, include the `-v` flag in your `aoc` command. An example output is shown below.

```
aoc: Environment checks are completed successfully.
You are now compiling the full flow!!
aoc: Selected target board <board_name>
aoc: Running OpenCL parser...
aoc: OpenCL parser completed successfully.
aoc: Compiling...
aoc: Linking with IP library ...
aoc: First stage compilation completed successfully.
aoc: Setting up project for CvP revision flow...
aoc: Hardware generation completed successfully.
```

The offline compiler displays the line `aoc: Hardware generation completed successfully.` to signify the completion of the compilation process.

For more information on the `--board <board_name>` option of the `aoc` command, refer to the *Compiling a Kernel for a Specific FPGA Board (--board <board\_name>)* section of the *Intel FPGA SDK for OpenCL Programming Guide*.

For more information on the `-v` option of the `aoc` command, refer to the *Generating Compilation Progress Report (-v)* section of the *Intel FPGA SDK for OpenCL Programming Guide*.

For more information on the `-o <filename>` option of the `aoc` command, refer to the *Specifying the Name of an Intel FPGA SDK for OpenCL Offline Compiler Output File (-o <filename>)* section of the *Intel FPGA SDK for OpenCL Programming Guide*.

### Related Links

- [Installing an FPGA Board](#) on page 31  
To install your board into a Linux host system, invoke the `install` utility command.
- [OpenCL Design Examples page](#)
- [Listing the Available FPGA Boards in Your Custom Platform \(--list-boards\)](#)
- [Compiling a Kernel for a Specific FPGA Board \(--board <board\\_name>\)](#)
- [Generating Compilation Progress Report \(-v\)](#)
- [Specifying the Name of an AOC Output File \(-o <filename>\)](#)

## 3.9 Updating the Hardware Image on the FPGA

If applicable, before you execute an OpenCL kernel program on the FPGA, ensure that the flash memory of the FPGA contains a hardware image created using a current version of the OpenCL software.

**Remember:** If your Custom Platform requires that you preload a valid OpenCL image into the flash memory, for every major release of the Quartus Prime Design Suite, program the flash memory of the FPGA with a hardware image compatible with the current version of the software.



### 3.9.1 Querying the Device Name of Your FPGA Board

Some OpenCL software utility commands require you to specify the device name (`<device_name>`). The `<device_name>` refers to the acl number (e.g. `acl0` to `acl31`) that corresponds to the FPGA device. When you query a list of accelerator boards, the OpenCL software produces a list of installed devices on your machine in the order of their device names.

- To query a list of installed devices on your machine, type `aocl diagnose` at a command prompt. The software generates an output that resembles the example shown below:

```
aocl diagnose: Running diagnostic from ALTERAOCLSDKROOT/board/<board_name>/
<platform>/libexec

Verified that the kernel mode driver is installed on the host machine.

Using board package from vendor: <board_vendor_name>
Querying information for all supported devices that are installed on the host
machine ...

device_name  Status  Information
acl0         Passed  <descriptive_board_name>
            PCIe dev_id = <device_ID>, bus:slot.func = 02:00.00,
            at Gen 2 with 8 lanes.
            FPGA temperature=43.0 degrees C.
acl1         Passed  <descriptive_board_name>
            PCIe dev_id = <device_ID>, bus:slot.func = 03:00.00,
            at Gen 2 with 8 lanes.
            FPGA temperature = 35.0 degrees C.

Found 2 active device(s) installed on the host machine, to perform a full
diagnostic on a specific device, please run aocl diagnose <device_name>

DIAGNOSTIC_PASSED
```

### 3.9.2 Programming the Flash Memory of an FPGA

Configure the FPGA by loading the hardware image of an Intel FPGA SDK for OpenCL design example into the flash memory of the device. When there is no power, the FPGA retains the hardware configuration file in the flash memory. When you power up the system, it configures the FPGA circuitry based on this hardware image in the flash memory. Therefore, it is imperative that an OpenCL-compatible hardware configuration file is loaded into the flash memory of your FPGA.

Preloading an OpenCL image into the flash memory is necessary for the proper functioning of many Custom Platforms. For example, most PCIe-based boards require a valid OpenCL image in flash memory so that hardware on the board can use the image to configure the FPGA device when the host system powers up for the first time. If the FPGA is not configured with a valid OpenCL image, the system will fail to enumerate the PCIe endpoint, or the driver will not function.

Before running any designs, ensure that the flash memory of your board has a valid OpenCL image that is compatible with the current OpenCL software version. Consult your board vendor's documentation for board-specific requirements.



**Caution:** When you load the hardware configuration file into the flash memory of the FPGA, maintain system power for the entire loading process, which might take a few minutes. Also, do not launch any host code that calls OpenCL kernels or might otherwise communicate with the FPGA board.

To load your hardware configuration file into the flash memory of your FPGA board, perform the following tasks:

1. Install any drivers or utilities that your Custom Platform requires.
2. Verify that you set the `AOCL_BOARD_PACKAGE_ROOT` environment variable to point to the subfolder in your Custom Platform that contains the `board_env.xml` file. Open a shell and then type `echo $AOCL_BOARD_PACKAGE_ROOT` at the command prompt.  
If the returned path does not point to the location of the `board_env.xml` file within your Custom Platform, follow the instructions in *Setting the Intel FPGA SDK for OpenCL User Environment Variables* to modify the environment variable setting.

3. Download a design example for your Custom Platform.

*Remember:* Download design examples from the OpenCL Design Examples page, and extract the example to a location to which you have write access. Ensure that the location name does not contain spaces.

4. To load the hardware configuration file into the flash memory, invoke the `aocl flash <device_name> <design_example_filename>.aocx` command, where `<device_name>` refers to the acl number (e.g. `acl0` to `acl31`) that corresponds to your FPGA device, and `<design_example_filename>.aocx` is the hardware configuration file you create from the `<design_example_filename>.cl` file in the example design package.
5. Power down your device or computer and then power it up again.

Power cycling ensures that the FPGA configuration device retrieves the hardware configuration file from the flash memory and configures it into the FPGA.

**Warning:** Some Custom Platforms require you to power cycle the entire host system after programming the flash memory. For example, PCIe-based Custom Platforms might require a host system reboot to reenumerate the PCIe endpoint. Intel recommends that you power cycle the complete host system after programming the flash memory.

#### Related Links

- [OpenCL Design Examples](#)
- [Setting the Intel FPGA SDK for OpenCL User Environment Variables](#) on page 29  
You have the option to set the Intel FPGA SDK for OpenCL Linux user environment variables permanently or transiently.

### 3.10 Executing an OpenCL Kernel on an FPGA

You must build your OpenCL host application with the `Makefile` file, and run the application by invoking the `hello_world` executable. You need GNU development tools such as `gcc` and `make` to build the OpenCL application.

#### Related Links

[Building the Host Application](#) on page 34



Build the host executable with the  
`<path_to_exm_opencl_hello_world_x64_linux_<version>>/  
hello_world/Makefile` file.

### 3.10.1 Running the Host Application

To execute the OpenCL kernel on the FPGA, run the Linux host application that you built from the Makefile.

1. Add the path `$ALTERAOCLSDKROOT/host/linux64/lib` to the `LD_LIBRARY_PATH` environment variable.
2. At a command prompt, navigate to the host executable within the `<path_to_exm_opencl_hello_world_x64_linux_<version>>/hello_world/bin` directory.
3. Invoke the `hello_world` executable.  
The `hello_world` executable executes the kernel code on the FPGA.

### 3.10.2 Output from Successful Kernel Execution

When you run the host application to execute your OpenCL kernel on the target FPGA, the OpenCL software notifies you of a successful kernel execution.

Example output:

```
Reprogramming device [0] with handle 1
Querying platform for info:
=====
CL_PLATFORM_NAME                = Intel(R) FPGA SDK for OpenCL(TM)
CL_PLATFORM_VENDOR              = Intel Corporation
CL_PLATFORM_VERSION = OpenCL 1.0 Intel(R) FPGA SDK for OpenCL(TM), Version
<version>

Querying device for info:
=====
CL_DEVICE_NAME                  = <board name> : <descriptive board name>
CL_DEVICE_VENDOR                = <board vendor name>
CL_DEVICE_VENDOR_ID             = <board vendor ID>
CL_DEVICE_VERSION = OpenCL 1.0 Intel(R) FPGA SDK for OpenCL(TM), Version
<version>
CL_DRIVER_VERSION                = <version>
CL_DEVICE_ADDRESS_BITS          = 64
CL_DEVICE_AVAILABLE            = true
CL_DEVICE_ENDIAN_LITTLE         = true
CL_DEVICE_GLOBAL_MEM_CACHE_SIZE = 32768
CL_DEVICE_GLOBAL_MEM_CACHELINE_SIZE = 0
CL_DEVICE_GLOBAL_MEM_SIZE       = 8589934592
CL_DEVICE_IMAGE_SUPPORT         = true
CL_DEVICE_LOCAL_MEM_SIZE        = 16384
CL_DEVICE_MAX_CLOCK_FREQUENCY  = 1000
CL_DEVICE_MAX_COMPUTE_UNITS     = 1
CL_DEVICE_MAX_CONSTANT_ARGS     = 8
CL_DEVICE_MAX_CONSTANT_BUFFER_SIZE = 2147483648
CL_DEVICE_MAX_WORK_ITEM_DIMENSIONS = 3
CL_DEVICE_MEM_BASE_ADDR_ALIGN   = 8192
CL_DEVICE_MIN_DATA_TYPE_ALIGN_SIZE = 1024
CL_DEVICE_PREFERRED_VECTOR_WIDTH_CHAR = 4
CL_DEVICE_PREFERRED_VECTOR_WIDTH_SHORT = 2
CL_DEVICE_PREFERRED_VECTOR_WIDTH_INT = 1
CL_DEVICE_PREFERRED_VECTOR_WIDTH_LONG = 1
CL_DEVICE_PREFERRED_VECTOR_WIDTH_FLOAT = 1
CL_DEVICE_PREFERRED_VECTOR_WIDTH_DOUBLE = 0
Command queue out of order?    = false
```





```
Command queue profiling enabled?           = true
Using AOCX: hello_world.aocx

Kernel initialization is complete.
Launching the kernel...

Thread #2: Hello from the Intel(R) FPGA OpenCL(TM) compiler!

Kernel execution is complete.
```

### 3.11 Uninstalling the Software

To uninstall the Intel FPGA SDK for OpenCL for Linux, remove the software package via the GUI uninstaller, then delete the software directory and restore all modified environment variables to their previous settings.

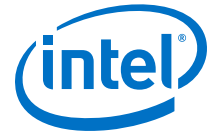
1. Remove the software package by performing one of the following tasks:
  - a. To uninstall the SDK, run the `aocl-<version>-uninstall.run` program located in the `<install directory>/uninstall` directories for the Quartus Prime Standard Edition software and the Quartus Prime Pro Edition software.
2. Remove `$ALTERAOCLSDKROOT/bin` from the `PATH` environment variable.
3. Remove `$ALTERAOCLSDKROOT/host/linux64/lib` from the `LD_LIBRARY_PATH` environment variable.
4. Remove the `ALTERAOCLSDKROOT` environment variable.
5. Remove the `QUARTUS_ROOTDIR_OVERRIDE` environment variable.

### 3.12 Uninstalling the FPGA Board

To uninstall an FPGA board for Linux, invoke the `uninstall` utility command, uninstall the Custom Platform, and unset the relevant environment variables. You must uninstall the existing FPGA board if you migrate your OpenCL application to another FPGA board that belongs to a different Custom Platform.

To uninstall your FPGA board, perform the following tasks:

1. Following your board vendor's instructions to disconnect the board from your machine.
2. Invoke the `aocl uninstall` utility command to remove the current host computer drivers (for example, PCIe drivers). The Intel FPGA SDK for OpenCL uses these drivers to communicate with the FPGA board.
3. Uninstall the Custom Platform.
4. Unset the `LD_LIBRARY_PATH` environment variable.
5. Unset the `AOCL_BOARD_PACKAGE_ROOT` environment variable.



## A Document Revision History

**Table 4. Document Revision History of the Intel FPGA SDK for OpenCL Getting Started Guide**

Date	Version	Changes
May 2017	2017.05.05	<ul style="list-style-type: none"> <li>Rebranded the Altera Client Driver (ACD) to the FPGA Client Driver (FCD).</li> <li>Updated the download instructions in <i>Downloading the Intel FPGA SDK for OpenCL</i> for Windows and Linux.</li> <li>Added reminders that folder names where you uncompress downloaded OpenCL design examples must not contain spaces.</li> </ul>
October 2016	2016.10.31	<ul style="list-style-type: none"> <li>Rebranded the Altera SDK for OpenCL to Intel FPGA SDK for OpenCL.</li> <li>Rebranded the Altera Offline Compiler to Intel FPGA SDK for OpenCL Offline Compiler.</li> <li>In <i>Installing an FPGA Board</i> for Windows and Linux, provided the following updates:                             <ul style="list-style-type: none"> <li>Noted that the SDK supports multi-Custom Platform installation. To use the SDK utilities on each board in a multi-Custom Platform installation, the <code>AOCL_BOARD_PACKAGE_ROOT</code> environment variable setting must correspond to the Custom Platform subdirectory of the associated board.</li> <li>Noted that in a multi-Custom Platform system, the host program should use ACD to discover the boards instead of directly linking to the MMD libraries.</li> </ul> </li> <li>In <i>Building the Host Application</i> for Windows, outlined the prerequisite tasks for setting up ACD and ICD for use with Microsoft Visual Studio 2015 prior to building the host application.</li> </ul>
May 2016	2016.05.02	<ul style="list-style-type: none"> <li>Replaced the lists of supported Windows and Linux versions to a link to the Operating System Support page on the Altera website.</li> <li>Added the <code>%ALTERAOCLSDKROOT%\windows64\bin</code> setting to the list of Windows environment variables.</li> <li>Corrected the Windows instructions for setting the <code>CL_CONTEXT_EMULATOR_DEVICE_ALTERA</code> variable for emulating multiple devices.</li> </ul>
November 2015	2015.11.02	<ul style="list-style-type: none"> <li>Changed instances of <i>Quartus II</i> to <i>Quartus Prime</i>.</li> <li>Added Windows 8.1 to supported Windows versions.</li> <li>Modified download and installation instructions for the tar file that includes the AOCL, Quartus Prime software, and device support.</li> <li>Deprecated and removed AOCL-only installation instructions because they are invalid for the current version.</li> <li>Added instructions to verify host runtime functionality by emulating the <code>hello_world</code> example design.</li> <li>Modified the figure <i>FPGA Programming Overview</i> to include emulation in the programming flow.</li> <li>Updated uninstallation instructions.</li> </ul>
May 2015	15.0.0	<ul style="list-style-type: none"> <li>Reorganized instructions into the following sections:                             <ul style="list-style-type: none"> <li>Getting Started with the AOCL on Windows</li> <li>Getting Started with the AOCL on Linux</li> </ul> </li> </ul>

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Date	Version	Changes
December 2014	14.1.0	<ul style="list-style-type: none"> <li>• Reorganized information flow.</li> <li>• Updated Red Hat Enterprise Linux (RHEL) version support.</li> <li>• Included the <i>Contents of the AOCL</i> section.</li> <li>• Updated licensing instructions for the new Altera Software Development Kit (SDK) for OpenCL (AOCL) single license.</li> <li>• Updated board uninstallation instructions to include the <code>aocl uninstall</code> utility command.</li> <li>• Included information on the <code>init_openc1</code> script for setting environment variables.</li> <li>• Grouped software and board uninstallation instructions under <i>Uninstalling the Software and the FPGA Board</i>.</li> </ul>
June 2014	14.0.0	<ul style="list-style-type: none"> <li>• Updated the <i>Prerequisites</i> section.</li> <li>• Updated the figure <i>AOCL Installation Process Overview</i>.</li> <li>• Updated software download instructions.</li> <li>• Updated AOCL installation and uninstallation instructions for Windows.</li> <li>• For Linux systems:                             <ul style="list-style-type: none"> <li>— Added the sections <i>Installing the AOCL on Linux Using RPM</i> and <i>Uninstalling the AOCL on Linux Using RPM</i>.</li> <li>— Updated the section <i>Installing the AOCL on Linux Using the GUI Installer</i>.</li> </ul> </li> <li>• Added the section <i>Licensing the Software</i>.</li> <li>• Updated the section <i>Installing an FPGA Board</i> with updated instructions on querying your devices and running diagnostic tests.</li> <li>• Updated the section <i>Creating the FPGA Hardware Configuration File of an OpenCL Kernel</i>:                             <ul style="list-style-type: none"> <li>— Updated path that you have to set for <code>AOCL_BOARD_PACKAGE_ROOT</code>.</li> <li>— Updated example AOC output for compiling <code>hello_world.cl</code> with the <code>-v</code> option.</li> <li>— Updated AOC output.</li> </ul> </li> <li>• Added the section <i>Identifying the Device Name of Your FPGA Board</i>.</li> <li>• Modified instructions for building and running the host application with updated <code>hello_world</code> directory and file names.</li> <li>• Added the section <i>Uninstalling an FPGA Board</i>.</li> </ul>
December 2013	13.1.1	<ul style="list-style-type: none"> <li>• Updated the <i>Prerequisites</i> section to include a reminder to install Linux kernel source, headers, and GCC.</li> </ul>
November 2013	13.1.0	<ul style="list-style-type: none"> <li>• Reorganized information flow.</li> <li>• Updated the <i>Prerequisites</i> section.</li> <li>• Updated board installation instructions.</li> <li>• Updated software download instructions.</li> <li>• Inserted the section <i>Installing the AOCL and the Quartus II Software Together</i>.</li> <li>• Updated software installation and uninstallation instructions.</li> <li>• Inserted the following figures:                             <ul style="list-style-type: none"> <li>— <i>AOCL Installation Process Overview</i></li> <li>— <i>FPGA Programming Overview</i></li> </ul> </li> <li>• Removed the <i>Licensing</i> section.</li> <li>• Removed all board-specific installation and configuration instructions.</li> <li>• Changed example OpenCL application used to demonstrate kernel configuration and FPGA programming from <code>moving_average</code> to <code>hello_world</code>.</li> <li>• Inserted the section <i>Updating the Hardware Image on the FPGA</i>, which contained the updated flash programming instructions.</li> <li>• Removed the section <i>Installing the USB-Blaster Driver on Windows</i>.</li> </ul>

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Date	Version	Changes
		<ul style="list-style-type: none"> <li>• Updated output from successful execution of hello_world kernel on FPGA for Windows and Linux systems.</li> <li>• Removed the figure <i>Contents of the Moving Average Example</i>.</li> <li>• Removed the figure <i>Opening host.sln in Visual Studio</i>.</li> </ul>
June 2013	13.0 SP1.0	<ul style="list-style-type: none"> <li>• Updated requisite Quartus II and AOCL software versions from 13.0 to 13.0 SP1.</li> <li>• Inserted the figure <i>A Correct Windows Device Manager After Complete Board Driver Installation for a BittWare Board</i>.</li> <li>• Updated the vendor and device IDs in the <i>Verifying the Functionality of the BittWare Board</i> section for Windows.</li> <li>• Updated the AOCL installation instructions for Linux systems that do not contain a .cshrc or a .bashrc file in the directory.</li> <li>• Updated path to the AOCL design examples.</li> <li>• Updated the figure <i>Contents of the Moving Average Example</i>.</li> <li>• Updated flash programming instructions.</li> </ul>
May 2013	13.0.1	<ul style="list-style-type: none"> <li>• Renamed the OpenCL_SDK folder or directory to AOCL.</li> <li>• Inserted warning about the AOCL installation dependency on .cshrc and .bashrc files for Linux systems.</li> <li>• Included reminder to BittWare board users about installing the BittWare development software.</li> <li>• Inserted warning about potential Jungo WinDriver installation failure for systems running on Windows 7. Included reinstallation instructions.</li> <li>• Inserted warnings about error messages displayed for aocl commands that have not been implemented for the BittWare FPGA board.</li> <li>• Inserted caution message about setting the environment variable <i>AOCL_BOARD_PACKAGE_ROOT</i>.</li> <li>• Updated board driver installation procedures for Windows and Linux systems.</li> <li>• Modified the path to the default location of the AOCL for Windows and Linux systems.</li> <li>• Modified the path name added to the <i>PATH</i> environment variable when installing the AOCL on Linux systems. The path name should be <code>\$QUARTUS_ROOTDIR/bin</code> instead of <code>\$QUARTUS_ROOTDIR/bin64</code>.</li> </ul>
May 2013	13.0.0	<ul style="list-style-type: none"> <li>• Updated installation and compilation procedures.</li> <li>• Incorporated licensing procedure.</li> <li>• Updated flash programming procedure and moved it to Appendix A.</li> <li>• Updated links to software and documentation download pages.</li> </ul>
November 2012	12.1.0	Initial release.