DE1-SoC

OpenCL

OpenCL

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Chapter 1

Introduction

DE1-SoC, a robust hardware design platform built with Altera System-on-Chip (SoC) FPGA, is officially Altera certified board for Altera's Preferred Board Partner Program for OpenCL. This document gives introduction on how to setup OpenCL development environment, compile and execute example projects for DE1-SoC. Users can refer to Altera SDK for OpenCL Programming Guide for more details about OpenCL coding instruction.

http://www.altera.com/literature/hb/opencl-sdk/aocl_programming_guide.pdf

1.1 DE1-SoC OpenCL BSP

The DE1-SoC OpenCL Board Support Package (BSP) contains required resources for users to develop OpenCL project based on DE1-SoC Board. The BSP is available from the website:

http://cd-de1-soc.terasic.com

For Windows Host, please download DE1-SoC_openCL_BSP.zip. For Linux, please download the DE1-SoC_openCL_BSP.bz2. These two compressed files are only different in the compression type. Their contents are the same. **Figure 1-1** shows the contents of OpenCL BSP.
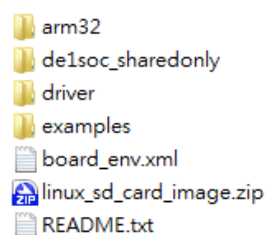
Figure 1-1 Contents of OpenCL BSP

1.2 System Requirements

The following items are required to setup OpenCL for DE1-SoC board:

- Terasic DE1-SoC board
- microSD card with at least 4GB capacity
- microSD card reader
- USB Cable (type A to mini-B)
- Ethernet Cable or USB-Storage
- Host PC with
  - USB Host port
  - 32GB memory is recommended
  - 64-bit Windows 7 or Linux
  - Win32 Disk Imager
  - PuTTY or Minicom(Linux) Utility
  - Altera Quartus II v14.0 installed with valid license
  - Altera OpenCL v14.0 installed with valid license
  - Altera SoC EDS v14.0 installed

1.3 OpenCL Architecture

An OpenCL project consists of OpenCL Kernel and Host Program, as shown in **Figure 1-2**. The Kernel is realized on the FPGA part of the SoC FPGA, and the Host Program is not the ARM part of the SoC FPGA. The Host Program is cross-compiled by Altera SoC EDS installed on Windows or Linux, and the Kernel is developed by Quartus and OpenCLK SDK installed on Windows or Linux.
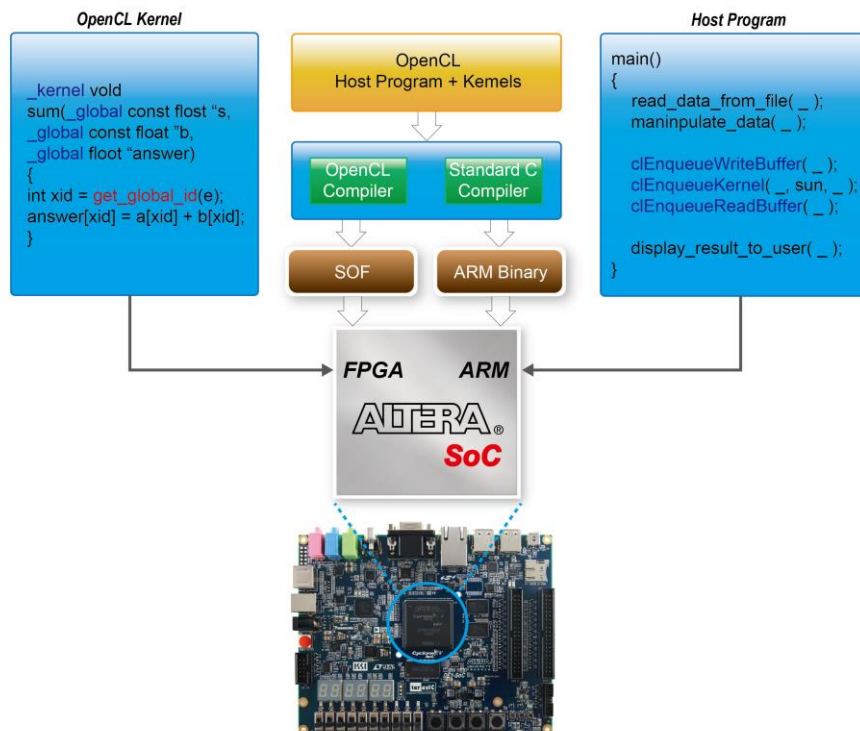
Figure 1-2 Altera SoC OpenCL architecture

1.4 Execute OpenCL Demo on DE1-SoC

This section describe how to execute OpenCL demo on DE1-SoC from the Linux image file included in DE1-SoC Board Support Package (BSP). Windows or Linux Host are required to setup the demo.

■ **Using Windows Host PC**

The following software should be installed on the Windows host PC to complete the setup.

● Disk Imager - available from http://sourceforge.net/projects/win32diskimager
● PuTTY- available from http://the.earth.li/~sgtatham/putty/latest/x86/putty.exe

The procedures to execute the hello_world and addVector demos are:

1. Download DE1-SoC BSP from http://cd-de1-soc.terasic.com and extract the Linux image file **linux_sd_card_image.img** from **linux_sd_card_image.zip**
2. Write the Linux image file **linux_sd_card_image.img** into the microSD card with Disk

Imager Utility.

3. Insert the SD card into the microSD card socket(J11).

4. Make sure the DIP switch (SW10) MSEL[4:0] = 01010.

5. Use an USB cable to connect your Host PC with the UART-to-USB port (J4) on DE1-SoC.if needed, the user should install the uart-to-usb device driver as described in the DE1-SoC Getting Started Guide.

6. Launch PuTTY utility on your Host PC. Make sure the baud rate is 115200.

7. Power on DE1-SoC to boot Linux. Login Linux with username 'root'(password is not required).

8. Type "source ./init_opencl.sh" to load the OpenCL Linux kernel driver and setup environment variable for OpenCL Run-Time library that is already installed on the SD Card.

9. Launch hello-world demo:
   ● Type "cd hello_world/" to go to the hello_world folder.
   ● Type "aocl program /dev/acl0 hello_world.aocx" to reconfigure the FPGA with the hello_world kernel.
   ● Type "./hello_world" to launch the hello_world host application, as shown in **Figure 1-3**.

10. Launch vectorAdd dmoe:
   ● Type "cd .." to return to the home directory.
   ● Then, type "cd vector_add" to go to the vector_add folder.
   ● Type "aocl program /dev/acl0 vectorAdd.aocx" to reconfigure the FPGA with the vectorADD kernel.
   ● Type "./vector_add" to launch the vector_add host application, as shown in **Figure 1-4**.

Figure 1-3 Hello-world demo

Figure 1-4 vectorAdd demo

■ Using Linux Host PC with Root Privilege

The following software should be installed on the Linux host PC to complete the setup.

- Minicom – terminal installed via command "yum install minicom" or "apt-get install minicom"

1. Download DE1-SoC BSP from http://cd-de1-soc.terasic.com and extract the linux image file **linux_sd_card_image.img** from **linux_sd_card_image.bz2.**
2. Write the Linux image file **linux_sd_card_image.img** into the microSD card with Disk Imager.
   - Insert the microSD card into a card reader and connect it to the host PC. If the microSD card already contains an image, existing partitions will be mounted automatically. If it happens, unmounts / eject all these partitions.
   - Check `dmesg|tail` command for which device name was assigned to the SD card. It's likely to be `/dev/sdb` (change /dev/sdb to the device name found in the previous step).
   - Run "`sudo dd if=linux_sd_card_image of=/dev/sdb bs=1M`"
   - Run "`sync`"
3. Insert the microSD card into the microSD card slot (J11) of DE1-SoC.

4. The DIP switch (SW10) on DE1-SoC for MSEL[4:0] must be set to 01010.

5. Use a USB cable to connect the host PC with the UART-to-USB port (J4) on DE1-SoC. Users should install the UART-to-USB device Linux driver as described in the FTDI driver download web page http://www.ftdichip.com/Drivers/VCP.htm.

6. Launch Minicom utility ("minicom –s" to configure at the first time) on the host PC. The baud rate should be set to 115200.

7. Power on DE1-SoC to boot Linux and log in as root. There's no password required.

8. Type "source ./init_opencl.sh" to load the OpenCL Linux kernel driver and setup environment variables for OpenCL Run-Time Environment that is already installed on the microSD card.

9. Launch hello world demo:
   - Type "cd hello_world/" to change the current directory to the hello_world folder.
   - Type "aocl program /dev/acl0 hello_world.aocx" to reconfigure the FPGA with the hello_world kernel.
   - Type "./hello_world" to launch the hello_world host application, as shown in **Figure 1-3**.

10. Launch vector Add demo:
   - Type "cd .." to return to the home directory.
   - Type "cd vectorAdd" to change the directory to the vectorAdd folder.
   - Type "aocl program /dev/acl0 vectorAdd.aocx" to reconfigure the FPGA with the vectorADD kernel.
   - Type "./vector_add" to launch the vectorAdd host application, as shown in **Figure 1-4**.

Chapter 2

OpenCL on Windows

This chapter describes how to set up DE1-SoC OpenCL development environment in Windows 64-bit, build and execute OpenCL project on DE1-SoC. For more details about getting started with Altera OpenCL for Cyclone V SoC, please refer to:

http://www.altera.com/literature/hb/opencl-sdk/aocl_c5soc_getting_started.pdf

2.1 Software Installation

This section describes how to install the software required for developing OpenCL project on DE1-SoC.

■ Install Altera Quartus II and OpenCL SDK

Altera Quartus II and OpenCL SDK are available from the website:

http://dl.altera.com/opencl

For Quartus II installation, please make sure that the Cyclone V device package is selected.

■ Install Altera SoC EDS

Altera SoC EDS tool is required to cross-compile the Host Program for ARM processor. The software is available from the website:

Please make sure DS-5 is installed during the installation of SoC EDS.

■ **Install DE1-SoC OpenCL Board Support Package (BSP)**

After Quartus II and OpenCL SDK are installed, please create a new folder "terasic" under the folder "C:\altera\14.0\hld\board", assuming Quartus II is installed under the folder "C:\Altera \14.0". Please download the DE1-SoC BSP file **DE1-SoC_openCL_BSP.zip** from

http://cd-de1-soc.terasic.com

Please uncompress the zip file and copy the "de1soc" folder to the created "terasic" folder, as shown in **Figure 2-1**.
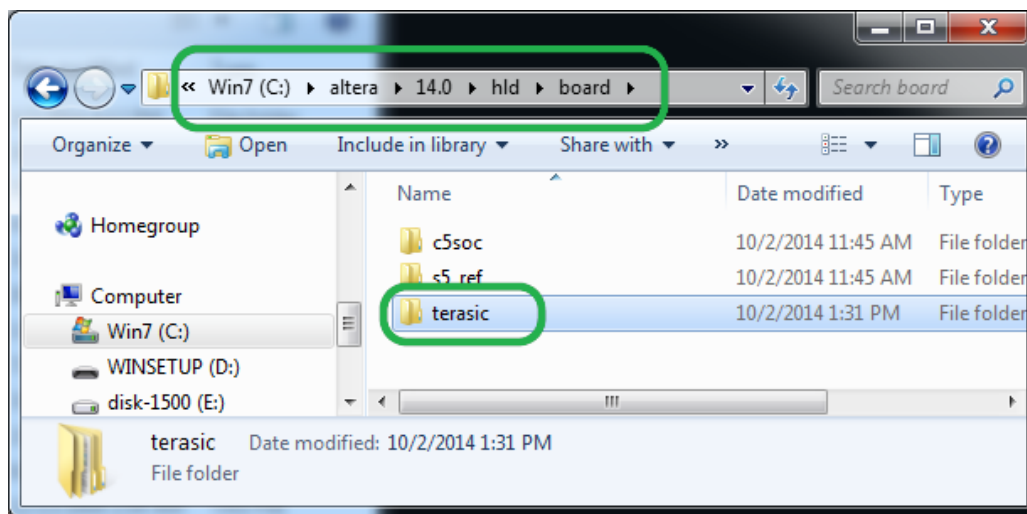
Figure 2-1 Copy "de1soc" folder to "c:/altera/14.0/hld/board/terasic" folder

2.2 OpenCL License Installation

An OpenCL license is required for Altera OpenCL SDK to compile OpenCL project successfully. Users can purchase the OpenCL license from either Altera or Terasic. A file named "license.dat" will be given upon purchasing OpenCL SDK license. For license installation, please store the file "license.dat" in the local disk drive "c:\" and create a Windows environment variable

LM_LICENSE_FILE with value "c:\license.dat". This environment variable value needs to match the actual location of "license.dat" file.

The procedures below show how to create the **LM_LICENSE_FILE** environment variable in Windows 7:

1. Open the Start Menu and right click on **Computer**. Select **Properties**.
2. Select **Advanced system settings.**
3. Select **Environment Variables** in the **Advanced** tab.
4. Select **New**.
5. In the popup **New User Variable** dialog shown in **Figure 2-2**, type "**LM_LICENSE_FILE**" in the **Variable name** field and type "**c:\license.dat**" in the **Variable value** field.
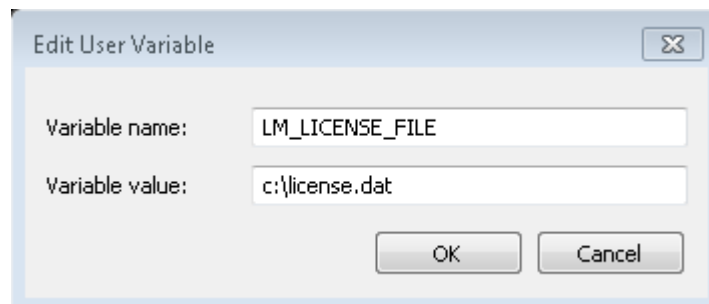
Figure 2-2 Setup LM_LICENSE_FILE environment variable

2.3 Configuration of OpenCL and DE1-SoC BSP

Please add the following paths into the PATH environment variable:

■ OpenCL Configuration

For OS to be able to find the OpenCL utilities correctly, developers need to add the following paths into the PATH environment variable:

1. %ALTERAOCLSDKROOT%\bin
2. %ALTERAOCLSDKROOT%\host\windows64\bin

Here are the procedures to add these two paths to the **PATH** environment variable on Windows 7:

1. Open the Start Menu and right click on **Computer**. Select **Properties**.

2. Select **Advanced system settings.**

3. In the **Advanced** tab, select **Environment Variables.**

4. Select **PATH** item, and click the **Edit** button.

5. In the popup **Edit User Variable** dialog as shown in **Figure 2-3**, add the following two strings into the **Value** edit box. Note, the strings should be separated by the symbol ";".
   - %ALTERAOCLSDKROOT%\bin
   - %ALTERAOCLSDKROOT%\host\windows64\bin
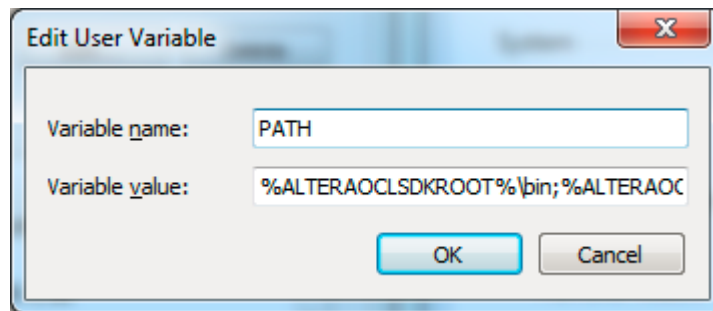
Figure 2-3 Modify PATH Environment Variable

■ **DE1-SoC BSP Configuration**

For Altera OpenCL SDK to find the kit location of DE1-SoC correctly, users need to create an environment variable **AOCL_BOARD_PACKAGE_ROOT** and set its value as:

"%ALTERAOCLSDKROOT%\board\terasic\de1soc"

The procedures to create the required **AOCL_BOARD_PACKAGE_ROOT** environment variable in Windows 7 are:

1. Open the Start Menu and right click on **Computer**. Select **Properties**.

2. Select **Advanced system settings**.

3. Select **Environment Variables i**n the **Advanced** tab.

4. Select **New**.

5. In the popup **New User Variable** dialog shown in **Figure 2-4**, type "**AOCL_BOARD_PACKAGE_ROOT**" in the **Variable name** field and type "**%ALTERAOCLSDKROOT%\board\terasic\de1soc**" in the **Variable value** field.
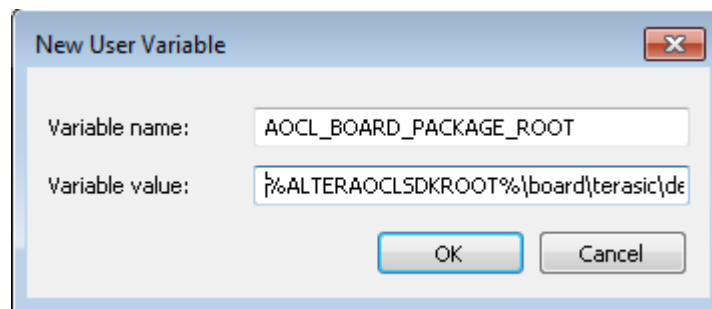
Figure 2-4 Setup AOCL_BOARD_PACKAGE_ROOT environment variable

2.4 OpenCL Environment Verification

This section shows how to confirm the OpenCL environment is setup correctly. Please open **Command Prompt** window by clicking Windows **Start** button and click **All Programs**. Click **Accessories**, and then click **Command Prompt**.

■ **Verify Utility**

Type "aocl version" command in the Command Prompt window and see if the version displayed matches the number shown in **Figure 2-5**. If the 'aocl' command cannot be found, please check if the "%ALTERAOCLSDKROOT%\bin" path is added to the **PATH** environment variable correctly.
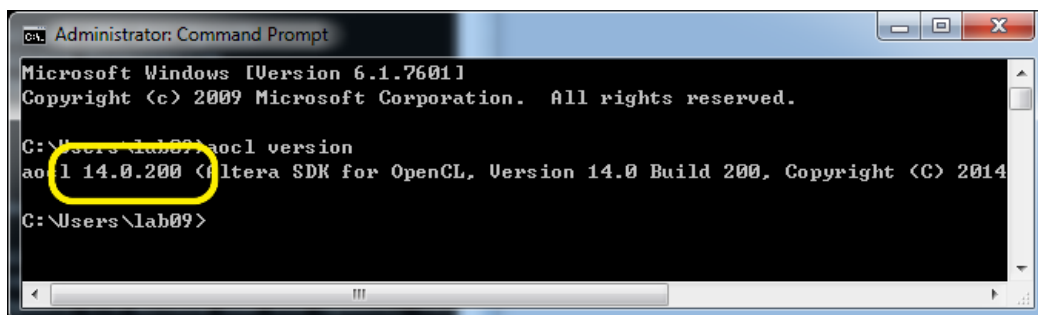
Figure 2-5 aocl version is listed in the Board list

■ **Verify Target Board**

Type "aoc --list-boards" command in the Command Prompt window and make sure

"de1soc_sharedonly" is listed in the **Board list**, as shown in **Figure 2-6**. If "de1soc_sharedonly" is not listed, please check if the **AOCL_BOARD_PACKAGE_ROOT** environment variable is assigned correctly.
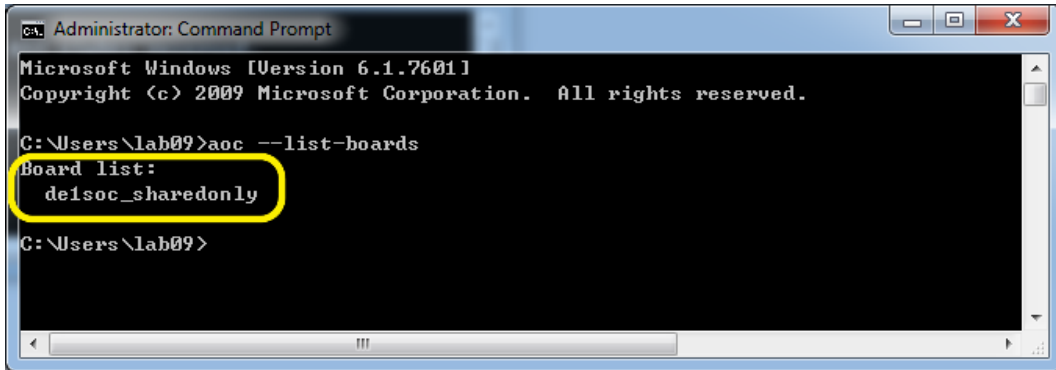
Figure 2-6 'de1soc_sharedonly' is listed in the Board list

■ **How to Check Environment Variables**

The value of environment variables can be retrieved by typing the 'echo' command in the Command Prompt window. For example, type "echo %AOCL_BOARD_PACKAGE_ROOT%" can retrieve the value of environment variable **AOCL_BOARD_PACKAGE_ROOT**.
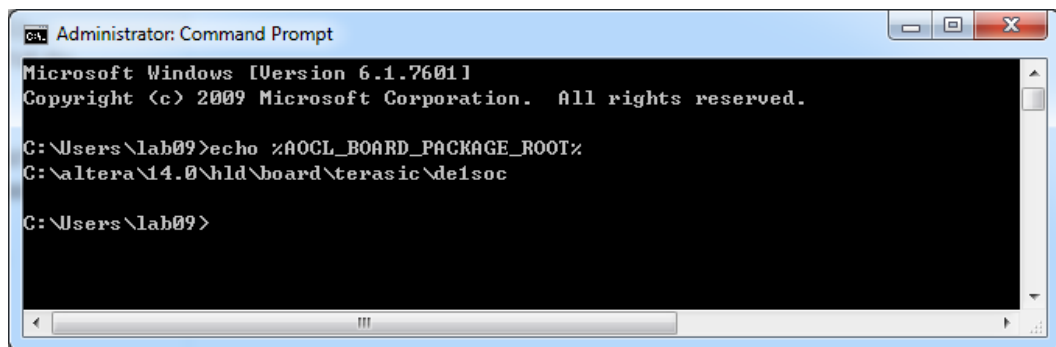
Figure 2-7 AOCL_BOARD_PACKAGE_ROOT path is listed in the Board list

2.5 Compile and Execute OpenCL Project

This section shows how to compile and execute OpenCL kernel and OpenCL Host Program provided in the DE1-SoC BSP. Users can follow the same procedures to compile and execute other OpenCL examples for DE1-SoC.

■ Compile OpenCL Kernel

The utility **aoc** (Altera SDK for OpenCL Kernel Compiler) is used to compile OpenCL kernel. Type "cd C:\altera\14.0\hld\board\terasic\de1soc\examples\boardtest" in the Command Prompt window to change the current directory to the folder **boardtest** and type:

"aoc device/boardtest.cl --sw-dimm-partition -o bin/boardtest.aocx"

to compile the OpenCL kernel. It will take approximately an hour to complete the compilation. When the compilation process is finished, OpenCL image file **boardtest.aocx** is generated under the **bin** folder. **Figure 2-8** shows the OpenCL kernel is compiled successfully. For the parameters of **aoc** to compile boardtest.cl, please refer to the README.txt included in the **boardtest** folder. For more details about the usage of **aoc**, please refer to the **Altera SDK for OpenCL Programming Guide**:

http://www.altera.com/literature/hb/opencl-sdk/aocl_programming_guide.pdf

Figure 2-8 Screenshot of OpenCL kernel compiled successfully by "aoc boardtest.cl"

■ Compile Host Program

The Host Program is compiled in Altera SoC EDS. Please launch embedded command shell by executing the "Embedded_Command_Shell.bat", as shown in **Figure 2-9**, under the folder "C:\altera\14.0\embedded", assuming Altera SoC EDS is installed under the directory "C:\altera\14.0"
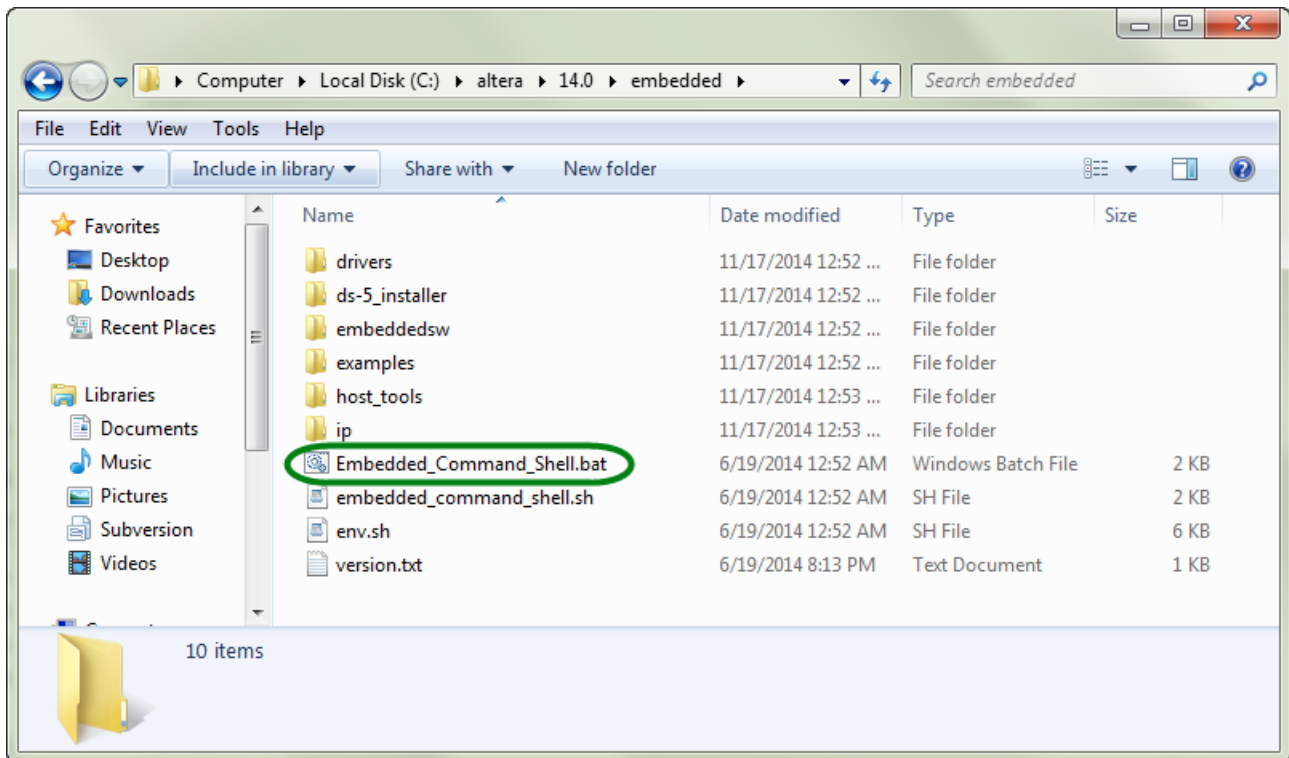
Figure 2-9 Location of embedded_command_Shell.bat

Type the following in the command shell:

"cd /cygdrive/c/altera/14.0/hld/board/terasic/de1soc/examples/boardtest/"

to change the current directory to the folder where board test project is located. Type "make" to build the host project shown in **Figure 2-10**. If the compilation is successful, a binary file **boardtest** will be generated under the boardtest folder.
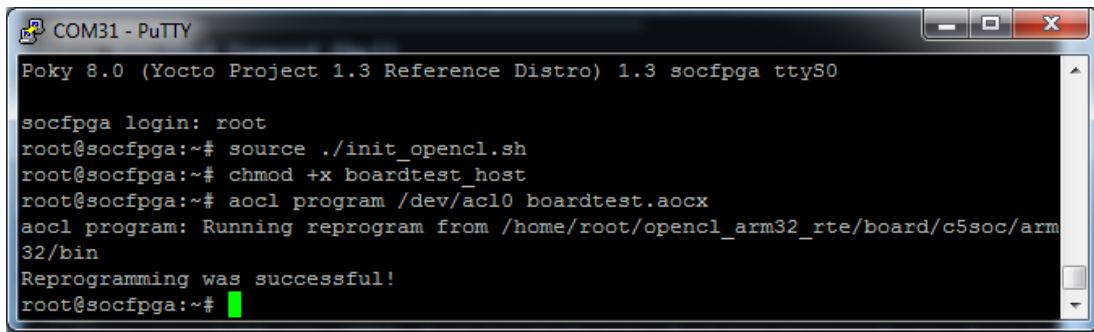
Figure 2-10 Type 'make' to build the boardtest host project

■ **Execute Board Test Project**

Please boot DE1-SoC with the Linux image from Chapter 1.4 for DE1-SoC OpenCL. Users need to copy both he kernel file **boardtest.aocx** and host file **boardtest_host** generated from previous section from the host PC to the DE1-SoC Linux System. Users can copy the file by typing Linux "scp" command through Ethernet or USB storage.
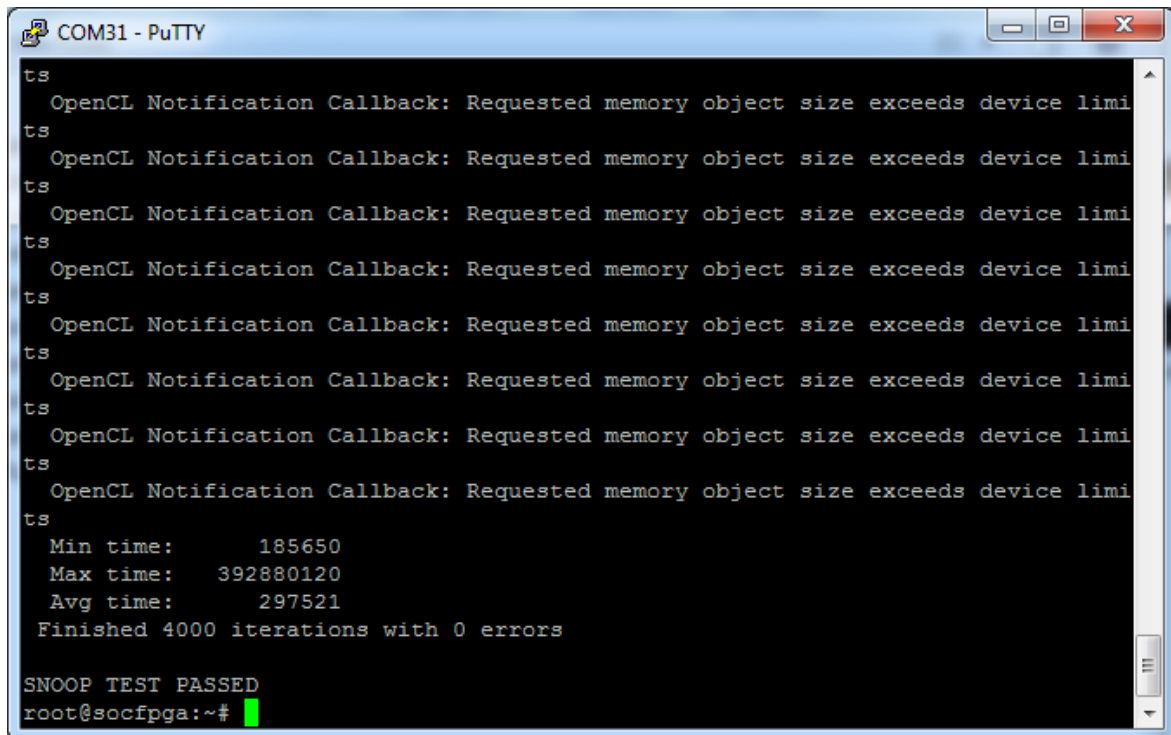
After these two files are copied to DE1-SoC Linux System, please go to the DE1-SoC Linux terminal. Type "source ./init_opencl.sh" in the terminal of DE1-SoC to setup OpneCL environment. Type "chmod +x boardtest_host" to add execution attribute to the host file and type "aocl program /dev/acl0 boardtest.aocx" to configure the FPGA, as shown in **Figure 2-11**. Type "./boardtest_host" to launch the host application, as shown in **Figure 2-12.**

Figure 2-11 "aocl program /dev/acl0 boardtest.aocx" configures FPGA successfully

Figure 2-12 "boardtest_host" is executed successfully

Chapter 3

OpenCL on Linux

This chapter describes how to setup the environment for the development of OpenCL on Linux, build OpenCL project including kernel and host application, followed by execution and verification.

For more details about OpenCL on Linux, please refer to Altera OpenCL Cyclone V SoC started guide:

http://www.altera.com/literature/hb/opencl-sdk/aocl_c5soc_getting_started.pdf

3.1 Software Installation

This section describes where to download and how to install the software required for OpenCL on DE1-SoC.

- **Download Altera Quartus II and OpenCL SDK**

Altera Quartus II and OpenCL SDK are available from Altera website:

http://dl.altera.com/opencl/

Follow the link and select Linux operation system with version 14.0, as shown in **Figure 3-1**.
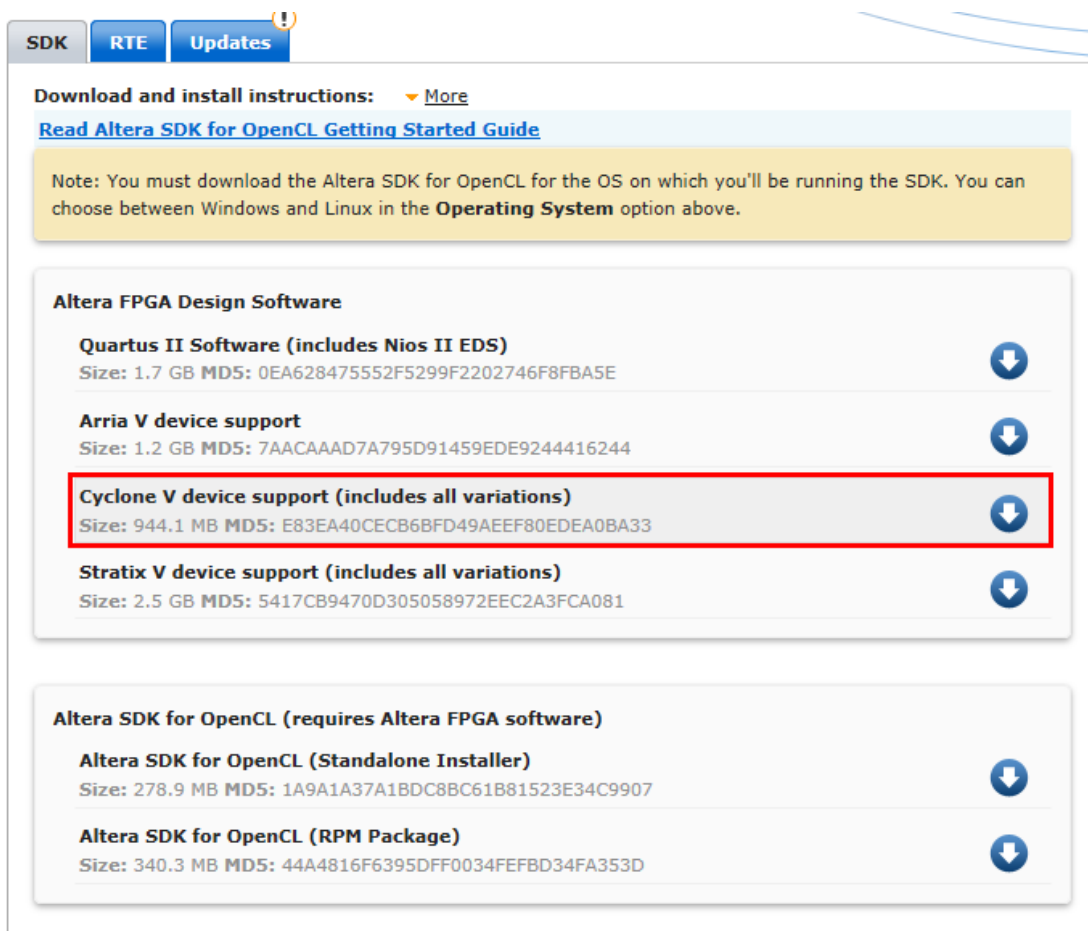
Figure 3-1 Website for the selection of OpenCL SDK Linux version

Choose Direct Download as the download method since the download manager is for Windows only. Click the arrows to download Altera FPGA Design Software and make sure the Cyclone V device is included, as shown in **Figure 3-2**. Users can download Altera SDK for OpenCL as standalone installer or RPM package.

Figure 3-2 Download Altera OpenCL SDK Linux version with Cyclone V device support

- **Install Altera SoC EDS**

Altera SoC EDS tool is required to cross-compile the host program for ARM processor. The software is available from the website:

http://dl.altera.com/soceds

Please make sure DS-5 is installed during the installation of SoC EDS.

- **Install DE1-SoC OpenCL Board Support Package (BSP)**

After Quartus II and OpenCL SDK are installed, please copy the terasic folder to the Altera OpenCL SDK folder "/root/altera/14.0/", as shown in **Figure 3-3**.
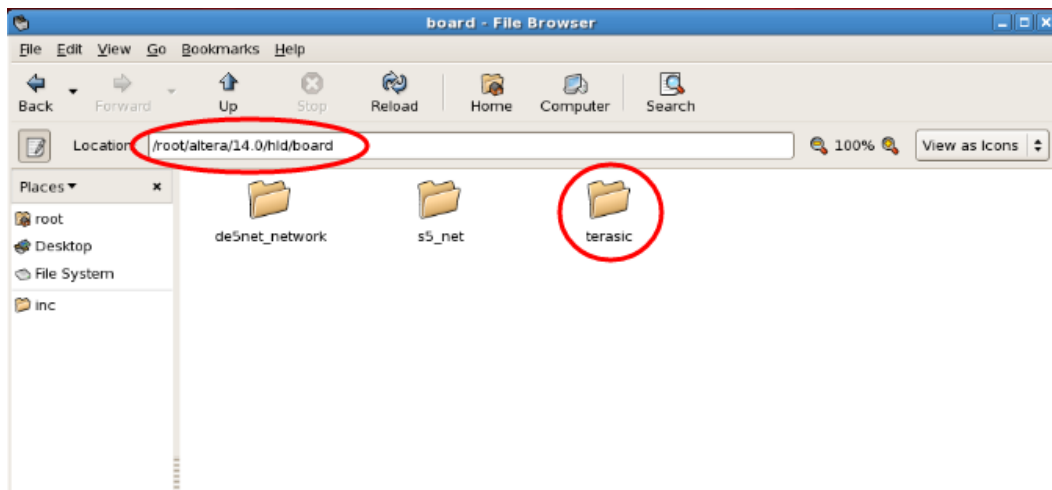
Figure 3-3 Copy the terasic folder to the /root/altera/14.0/hld/bolard folder

3.2 OpenCL License Installation

A license for OpenCL is required to compile OpenCL project with Altera OpenCL SDK. Users can purchase the OpenCL license from either Altera or Terasic. After users have obtained a license file named "license.dat", it needs to be saved to the local disk such as "/root/altera/14.0/hld/license.dat". Users also need to create an environment variable **LM_LICENSE_FILE** set its value as "/root/altera/14.0/hld/license.dat", which corresponds to the actual location of the license file.

The next section will describe how to setup the license environment.

3.3 Configuration of Environment Variables

If users install the ALTERA FPGA development software and OpenCL SDK on a system that does not contain any .cshrc or bash resource file (.bashrc) in the directory, the ALTERAOCLSDKROOT and PATH environment variables must be set manually. Users also need to create an environment variable **AOCL_BOARD_PACKAGE_ROOT** for DE1-SoC board for Altera OpenCL SDK to find the kit location of DE1-SoC correctly and set its value as:

"%ALTERAOCLSDKROOT%\board\terasic\de1soc"

Alternatively, users can edit the "/etc/profile", and append the environment variables to it. Users can type "*gedit /etc/profile"* command in the Linux terminal to open the **profile** file with the **gedit** editor tool and append the following settings to the **profile** file. After the edit is complete, save the file and type "*source /etc/profile"* command in the Linux terminal to apply the settings.

---

export **QUARTUS_ROOTDIR**=/root/altera/14.0/quartus

export **ALTERAOCLSDKROOT**=/root/altera/14.0/hld

export **PATH**=$PATH:"$QUARTUS_ROOTDIR"/bin: "$ALTERAOCLSDKROOT"/linux64/bin :
"$ALTERAOCLSDKROOT"/bin:/root/altera/14.0/embedded/ds-5/bin

export **LD_LIBRARY_PATH**="$ALTERAOCLSDKROOT"/linux64/lib

export **AOCL_BOARD_PACKAGE_ROOT**="$ALTERAOCLSDKROOT"/ board/terasic/de1soc

export **QUARTUS_64BIT**=1

export **LM_LICENSE_FILE**= /root/altera/14.0/hld/license.dat

---
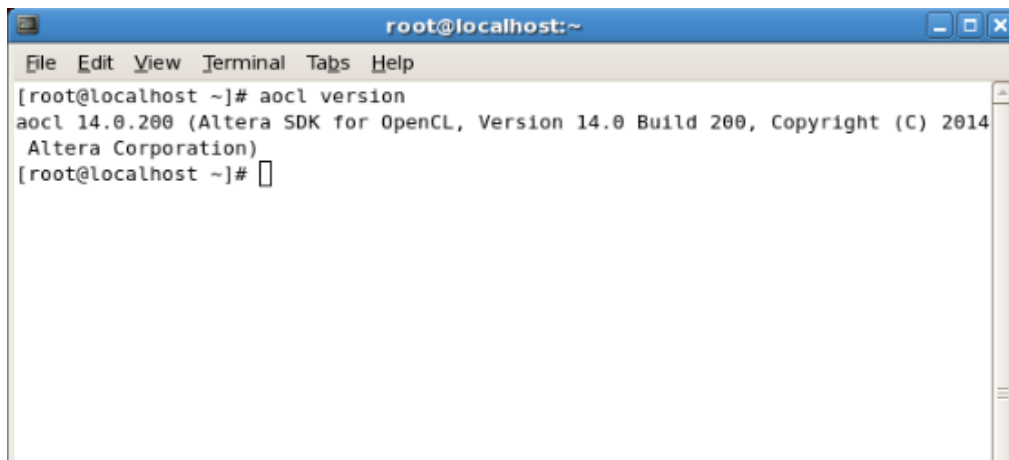
3.4 Verification of OpenCL Environment

This section shows how to make sure the OpenCL environment is setup correctly. Please open the terminal window on Linux.

- **Verify Utility**

Type "aocl version" command in terminal and make sure the aocl version reported is as shown in Figure 3-4. If the 'aocl' command cannot be found, please check if the

"%ALTERAOCLSDKROOT%\bin" path is added to the **PATH** environment variable correctly.

Figure 3-4 The information about aocl version

- **Verify Target Board**

Type "aoc --list-boards" command in the terminal and make sure "de1soc_sharedonly" is listed in Board list, as shown in **Figure 3-5.** If "de1soc_sharedonly" is not listed, please check if the **AOCL_BOARD_PACKAGE_ROOT** environment variable is assigned correctly.

Figure 3-5 'de1soc_sharedonly' is listed in Board list

- **Check Environment Variables**

The values of environment variables can be retrieved by the 'echo' command in the terminal. For example, type "echo %AOCL_BOARD_PACKAGE_ROOT%" can dump the value of environment variable **AOCL_BOARD_PACKAGE_ROOT**, as shown in **Figure 3-6.**

Figure 3-6 Check the environment variables

3.5 Build and Execute OpenCL Project

This section shows how to compile and test OpenCL example project and OpenCL host program provided in DE1-SoC BSP. Users can follow the same procedures to compile and test other OpenCL projects for DE1-SoC.

- **Compile OpenCL Kernel**

The utility **aoc** (Altera SDK for OpenCL Kernel Compiler) is used to compile OpenCL kernel. Type "*cd /root/altera/14.0/hld/board/terasic/de1soc/examples/boardtest*" in the terminal to change the current directory to the **boardtest** project folder. Type:

"aoc device/boardtest.cl --sw-dimm-partition -o bin/boardtest.aocx"

to compile the OpenCL kernel. The compilation process will take about one hour. When the compilation process is finished, an OpenCL image file **boardtest.aocx** is generated under the **bin** folder. Figure 3-7 is the screenshot when the OpenCL kernel is compiled successfully. For the parameters of **aoc** to compile boardtest.cl, please refer to the README.txt in the boardtest folder. For more informatoin about the usage of **aoc**, please refer to the **Altera SDK for OpenCL Programming Guide**:

http://www.altera.com/literature/hb/opencl-sdk/aocl_programming_guide.pdf

Figure 3-7 OpenCL kernel is compiled successfully

- **Compile Host Program**

Altera SoC EDS is used to compile the host program. Please launch embedded command shell by executing the "Embedded_Command_Shell.sh", as shown in **Figure 3-8**, under the folder "/root/altera/14.0/embedded", assuming Altera SoC EDS is installed under the directory "/root/altera/14.0/".
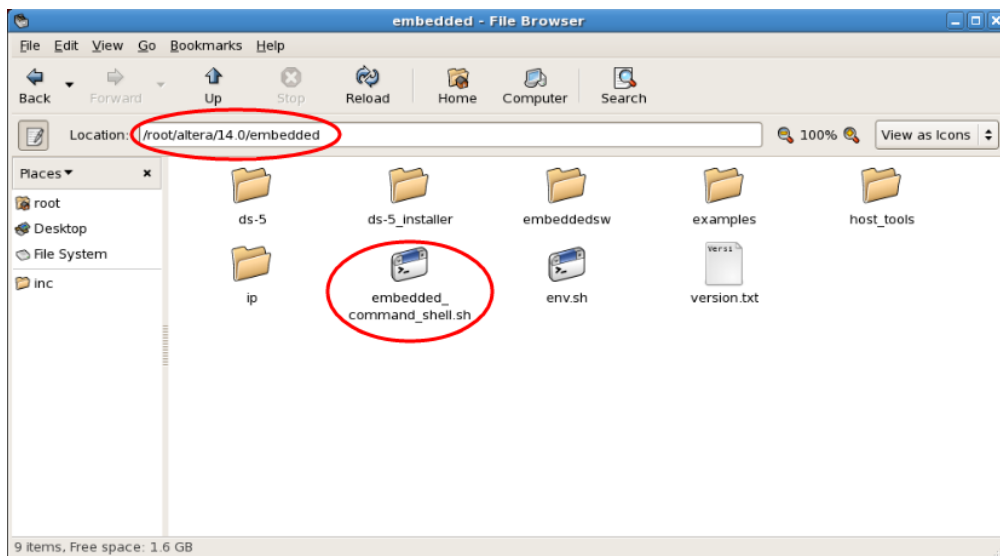
Figure 3-8 Location of Embedded_Command_Shell.sh

In the command shell, please type:

"cd /root/altera/14.0/hld/board/terasic/de1soc/examples/boardtest/"

and the current directory will be changed to the folder where board test project is located. Type "make" to build the host project, as shown in **Figure 3-9**. If the host project is compiled successfully, a host binary file **boardtest** will be generated under the boardtest folder.

Figure 3-9 Type 'make' to build the boardtest host project

- **Test boardtest project**
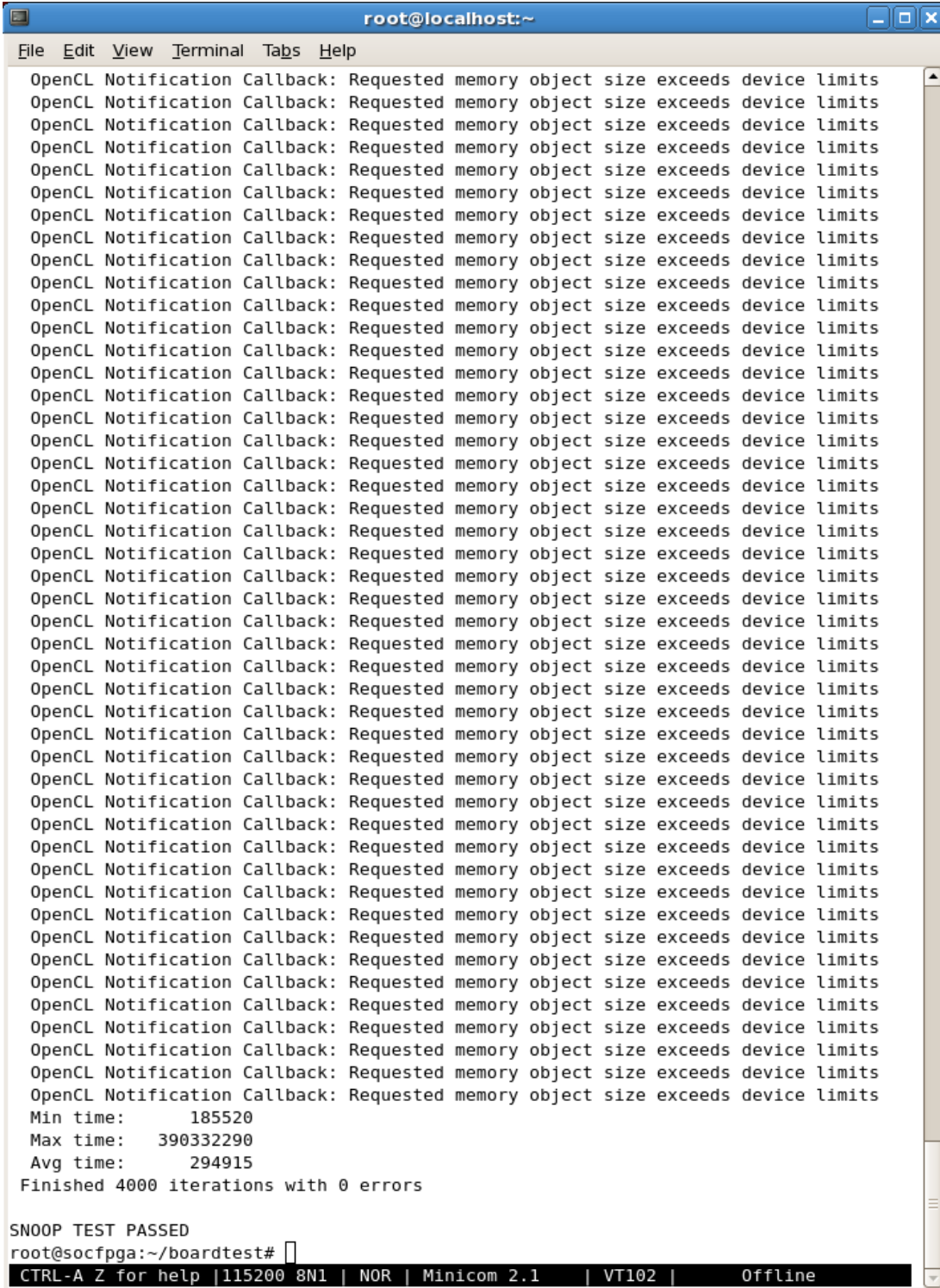
Please boot DE1-SoC with the Linux image for DE1-SoC OpenCL described in Chapter 1.4. Users need to copy the generated kernel file **boardtest.aocx** and the host file **boardtest** from the host PC to the Linux system running on DE1-SoC by establishing SSH connection via Ethernet with "scp" command or via usb-storage with "mount" command.

After these two files are copied to the Linux system running on DE1-SoC, please add executable attribution with "chmod" command and type "aocl program /dev/acl0 boardtest.aocx" to configure the FPGA, as shown in **Figure 3-10**. Type "./boardtest" to launch the host application, as shown in **Figure 3-11.**

Figure 3-10 "aocl program /dev/acl0 boardtest.aocx" configures the FPGA successfully

Figure 3-11 "boardtest" test is successful