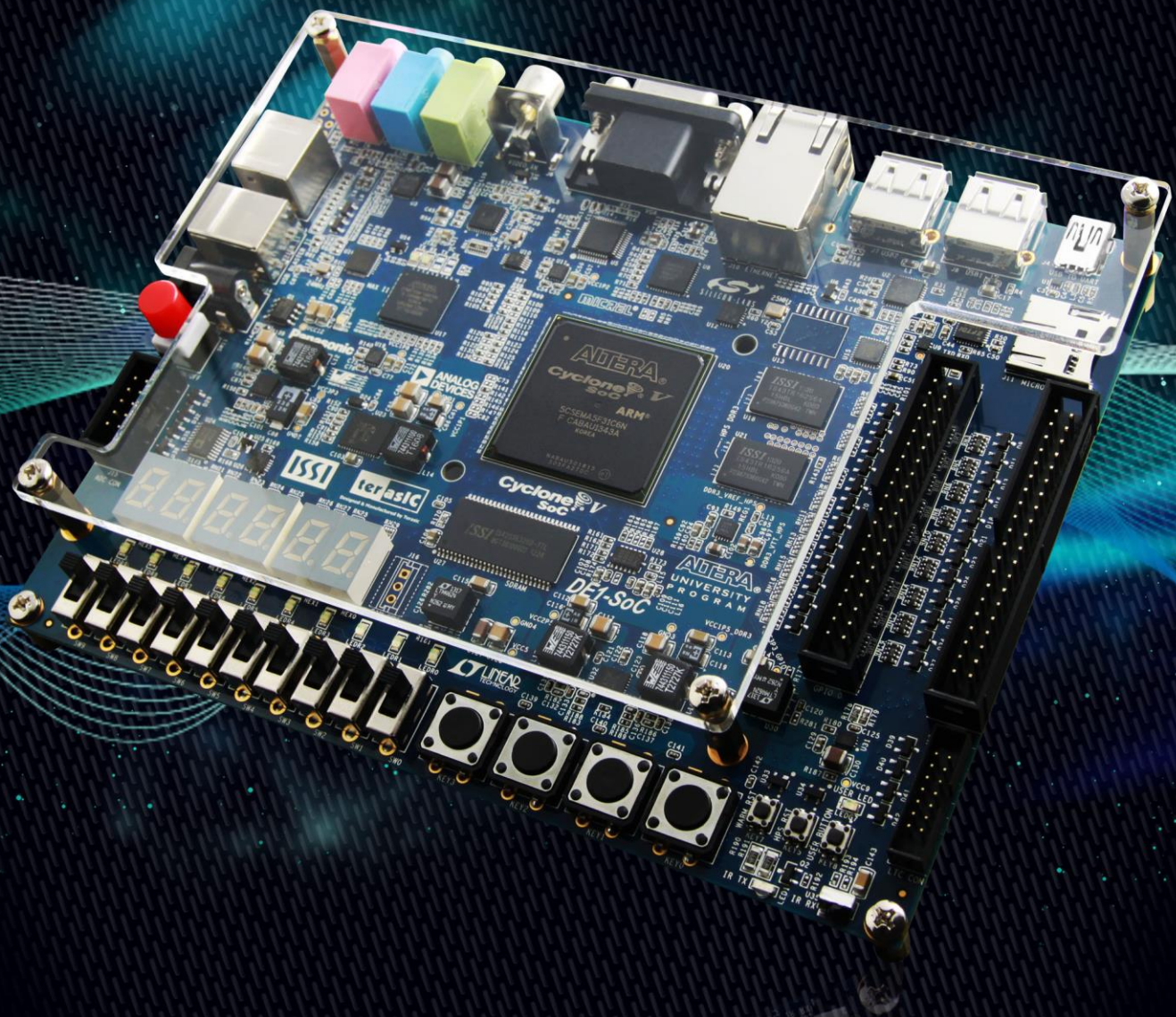


# DE1-SoC

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.

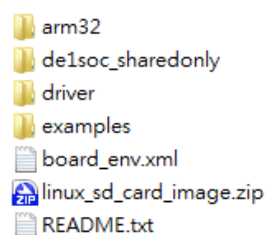
[http://www.altera.com/literature/hb/opencl-sdk/aocl\\_programming\\_guide.pdf](http://www.altera.com/literature/hb/opencl-sdk/aocl_programming_guide.pdf)

### **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.

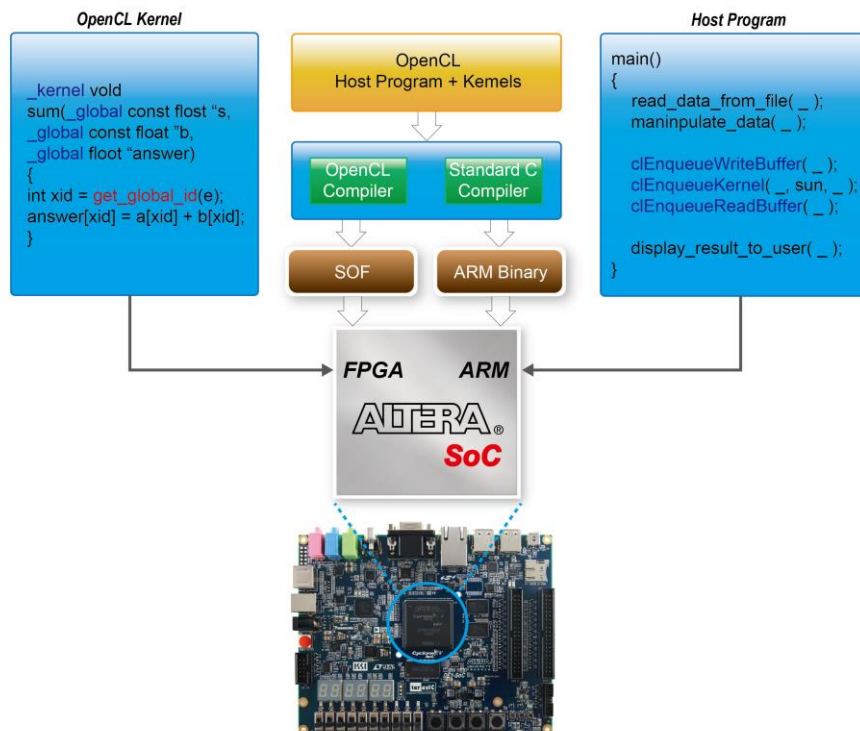


Figure 1-2 Altera SoC OpenCL architecture

## 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**.

```

COM31 - PuTTY
socfpga login: root
root@socfpga:~# source ./init_openc1.sh
root@socfpga:~# cd hello_world/
root@socfpga:~/hello_world# aocl program /dev/acl0 hello_world.aocx
aocl program: Running reprogram from /home/root/openc1_arms2_rte/board/c5soc/arm
32/bin
Reprogramming was successful.
root@socfpga:~/hello_world# ./hello_world
Querying platform for info:
=====
CL_PLATFORM_NAME           = Altera SDK for OpenCL
CL_PLATFORM_VENDOR        = Altera Corporation
CL_PLATFORM_VERSION       = OpenCL 1.0 Altera SDK for OpenCL, Ver
sion 14.0

Querying device for info:
=====
CL_DEVICE_NAME             = de1soc_sharedonly : Cyclone V SoC Dev
elopment Kit
CL_DEVICE_VENDOR          = Altera Corporation
CL_DEVICE_VENDOR_ID       = 4466
CL_DEVICE_VERSION         = OpenCL 1.0 Altera SDK for OpenCL, Ver
sion 14.0
CL_DRIVER_VERSION         = 14.0
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 = 536870912
CL_DEVICE_IMAGE_SUPPORT   = false
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 = 134217728
CL_DEVICE_MAX_WORK_ITEM_DIMENSIONS = 3
CL_DEVICE_MAX_WORK_ITEM_DIMENSIONS = 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.

```

Figure 1-3 Hello-world demo

```

COM31 - PuTTY
root@socfpga:~/hello_world# cd ..
root@socfpga:~# cd vector_add
root@socfpga:~/vector_add# aocl program /dev/ac10 vectorAdd.aocx
aocl program: Running reprogram from /home/root/opencl_arm32_rte/board/c5soc/arm32/bin
Reprogramming was successful
root@socfpga:~/vector_add# ./vector_add
Initializing OpenCL
Platform: Altera SDK for OpenCL
Using 1 device(s)
  daisoc_sharedonly : Cyclone V SoC Development Kit
Using AOCX: vectorAdd.aocx
Launching for device 0 (1000000 elements)

Time: 107.171 ms
Kernel time (device 0): 6.932 ms

Verification: PASS
root@socfpga:~/vector_add#

```

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](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:

<http://dl.altera.com/soceds>

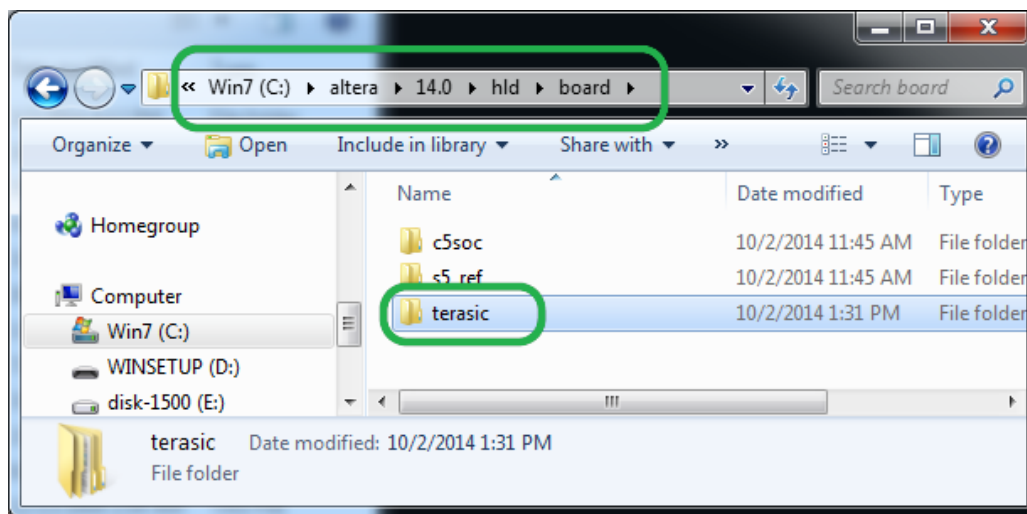
Please make sure DS-5 is installed during the installation of SoC EDS.

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

After Quartus II and OpenCL SDK are installed, please 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**

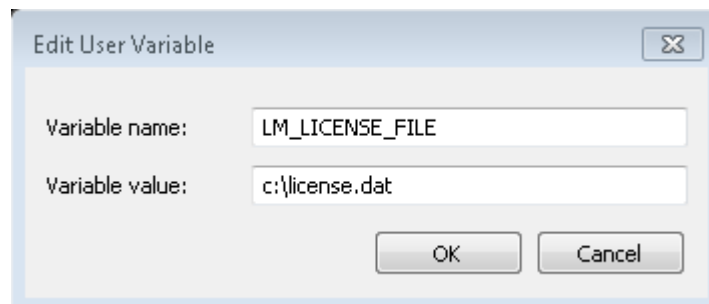
## 2.2 OpenCL License Installation

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**

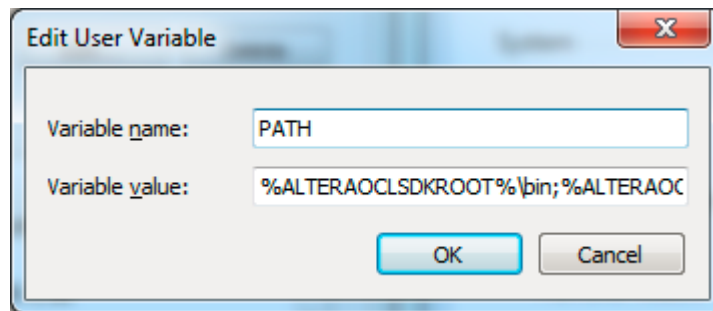
For OS to be able to find the OpenCL utilities correctly, developers need to add the following paths into the **PATH** environment variable:

1. %ALTEAOCLSDKROOT%\bin
2. %ALTEAOCLSDKROOT%\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 “;”.
  - %ALTEAOCLSDKROOT%\bin
  - %ALTEAOCLSDKROOT%\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:

“%ALTEAOCLSDKROOT%\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** in 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 “%ALTEAOCLSDKROOT%\board\terasic\de1soc” in the **Variable value** field.

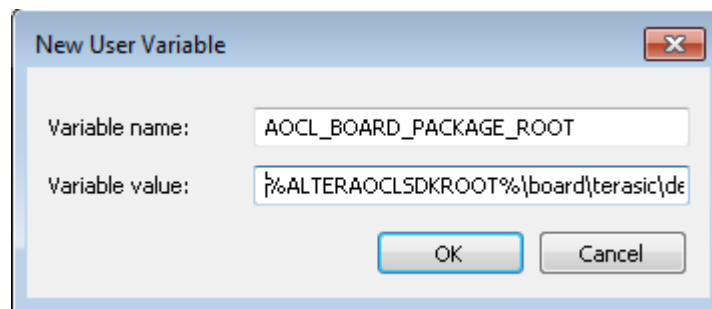


Figure 2-4 Setup AOCL\_BOARD\_PACKAGE\_ROOT environment variable

## 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 “%ALTEAOCLSDKROOT%\bin” path is added to the **PATH** environment variable correctly.

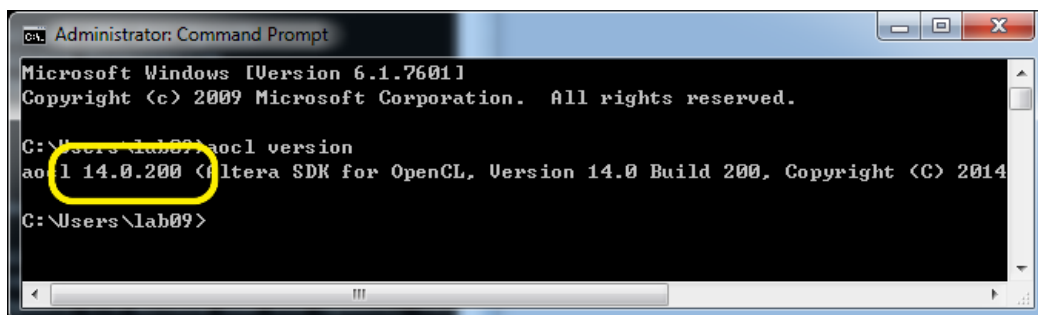
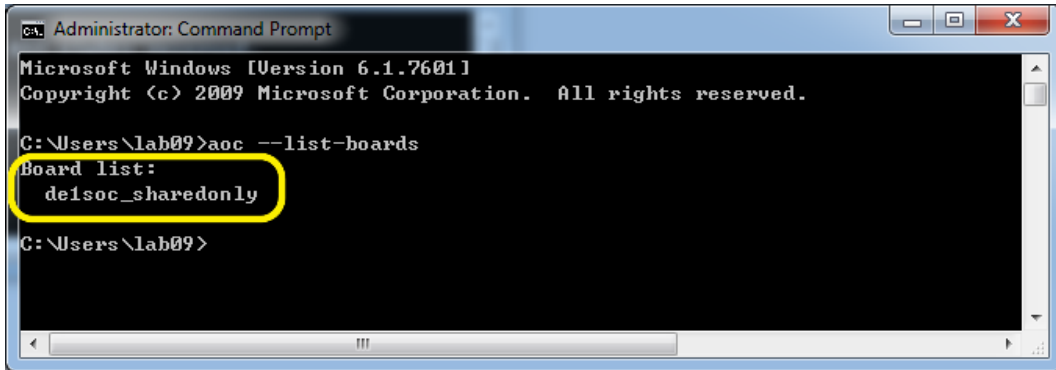


Figure 2-5 aocl version is listed in the Board list

### ■ Verify Target Board

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

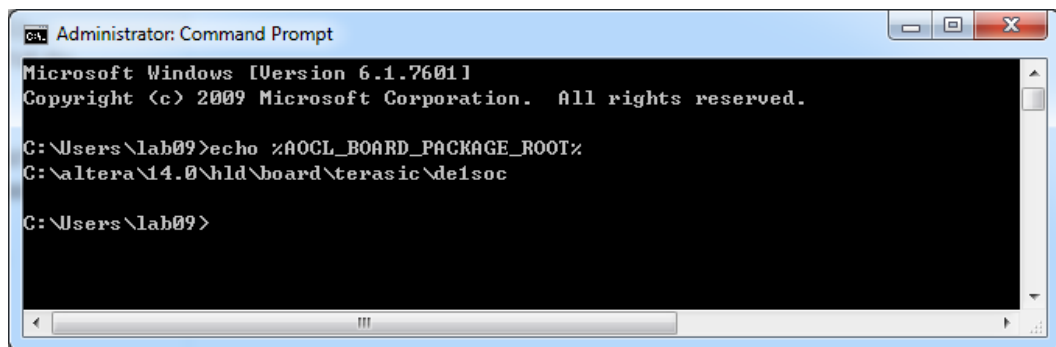
“de1soc\_sharedonly” is listed in the **Board list**, as shown in **Figure 2-6**. If “de1soc\_sharedonly” is not listed, please check if the **AOCL\_BOARD\_PACKAGE\_ROOT** environment variable is assigned correctly.



**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](http://www.altera.com/literature/hb/opencl-sdk/aocl_programming_guide.pdf)

```
Administrator: Command Prompt
with no 'restrict' may lead to low kernel performance
__global const uint *index,
    ^
10 warnings generated.
Warning: Unused kernel argument 'arg'
Warning: Unused kernel argument 'arg2'
Warning: Unused kernel argument 'arg'
Warning: Unused kernel argument 'arg2'
Warning: Unused kernel argument 'src'
Warning: Unused kernel argument 'dst'
Warning: Unused kernel argument 'arg'
Warning: Unused kernel argument 'arg2'

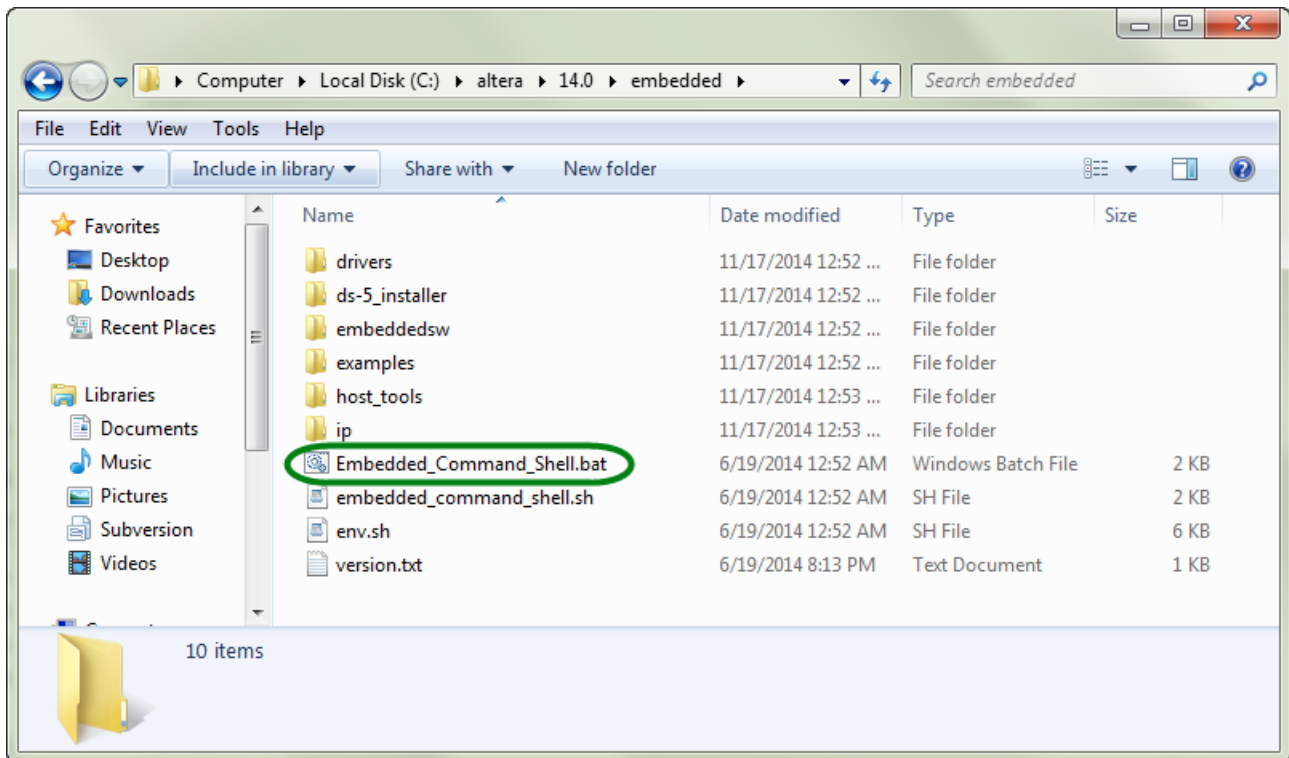
C:\altera\14.0\hld\board\terasic\de1soc\examples\boardtest>
```

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.

```

ca. /cygdrive/c/altera/14.0/hld/board/terasic/de1soc/examples/boardtest
-----
Altera Embedded Command Shell
Version 14.0
-----
lab09@lab09-PC ~
$ cd /cygdrive/c/altera/14.0/hld/board/terasic/de1soc/examples/boardtest/
lab09@lab09-PC /cygdrive/c/altera/14.0/hld/board/terasic/de1soc/examples/boardtest
$ make
arm-linux-gnueabi-g++ -fPIC host/src/main.cpp host/src/memspeed.cpp host/src/reorder.cpp host/src/reorder_ocl.cpp host/src/hostspeed.cpp host/src/hostspeed_ocl.cpp host/src/aclutil.cpp host/src/timer.cpp host/src/rwtest.cpp -o boardtest_host -DLINUX -IC:/altera/14.0/hld/host/include -LC:\altera\14.0\hld\board\terasic\de1soc\arm32\lib -LC:/altera/14.0/hld/host/arm32/lib -lalteracl -lalterahalmd -lalterammdpcie -lelf -lrt -lstdc++
lab09@lab09-PC /cygdrive/c/altera/14.0/hld/board/terasic/de1soc/examples/boardtest
$

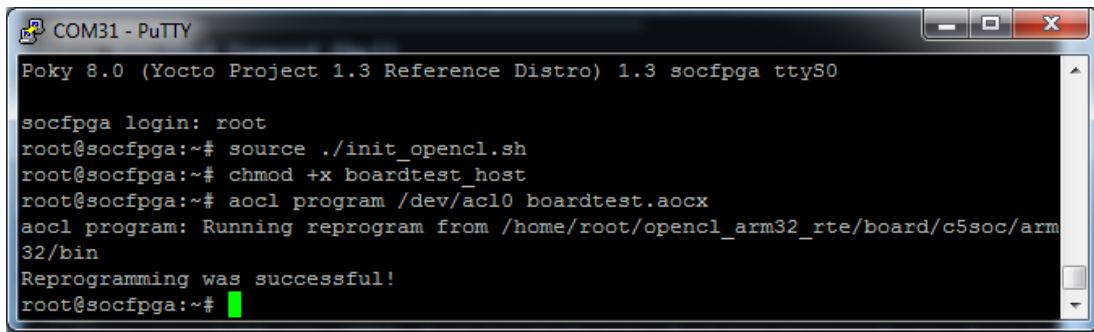
```

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 the 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.

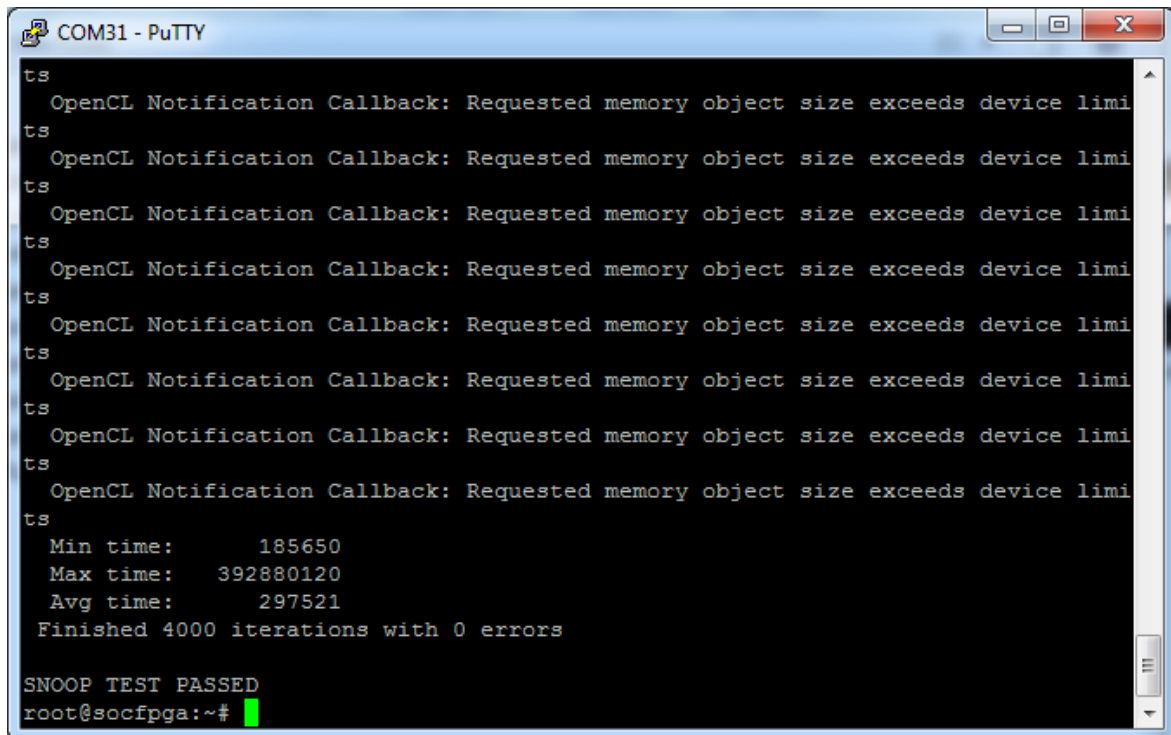
After these two files are copied to DE1-SoC Linux System, please go to the DE1-SoC Linux terminal. Type “source ./init\_opencl.sh” in the terminal of DE1-SoC to setup OpneCL environment. Type “chmod +x boardtest\_host” to add execution attribute to the host file and type “aocl program /dev/acl0 boardtest.aocx” to configure the FPGA, as shown in **Figure 2-11**. Type “./boardtest\_host” to launch the host application, as shown in **Figure 2-12**.



```
COM31 - PuTTY
Poky 8.0 (Yocto Project 1.3 Reference Distro) 1.3 socfpga ttyS0

socfpga login: root
root@socfpga:~# source ./init_openc1.sh
root@socfpga:~# chmod +x boardtest_host
root@socfpga:~# aocl program /dev/acl0 boardtest.aocx
aocl program: Running reprogram from /home/root/openc1_arm32_rte/board/c5soc/arm
32/bin
Reprogramming was successful!
root@socfpga:~# █
```

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



```
COM31 - PuTTY

ts
  OpenCL Notification Callback: Requested memory object size exceeds device limi
ts
  OpenCL Notification Callback: Requested memory object size exceeds device limi
ts
  OpenCL Notification Callback: Requested memory object size exceeds device limi
ts
  OpenCL Notification Callback: Requested memory object size exceeds device limi
ts
  OpenCL Notification Callback: Requested memory object size exceeds device limi
ts
  OpenCL Notification Callback: Requested memory object size exceeds device limi
ts
  OpenCL Notification Callback: Requested memory object size exceeds device limi
ts
  OpenCL Notification Callback: Requested memory object size exceeds device limi
ts
  OpenCL Notification Callback: Requested memory object size exceeds device limi
ts
  Min time:      185650
  Max time:     392880120
  Avg time:      297521
  Finished 4000 iterations with 0 errors

SNOOP TEST PASSED
root@socfpga:~# █
```

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](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**.

## Altera SDK for OpenCL™

Home > Support > Downloads > Altera SDK for OpenCL

Release date: June, 2014

Latest Release: v14.0

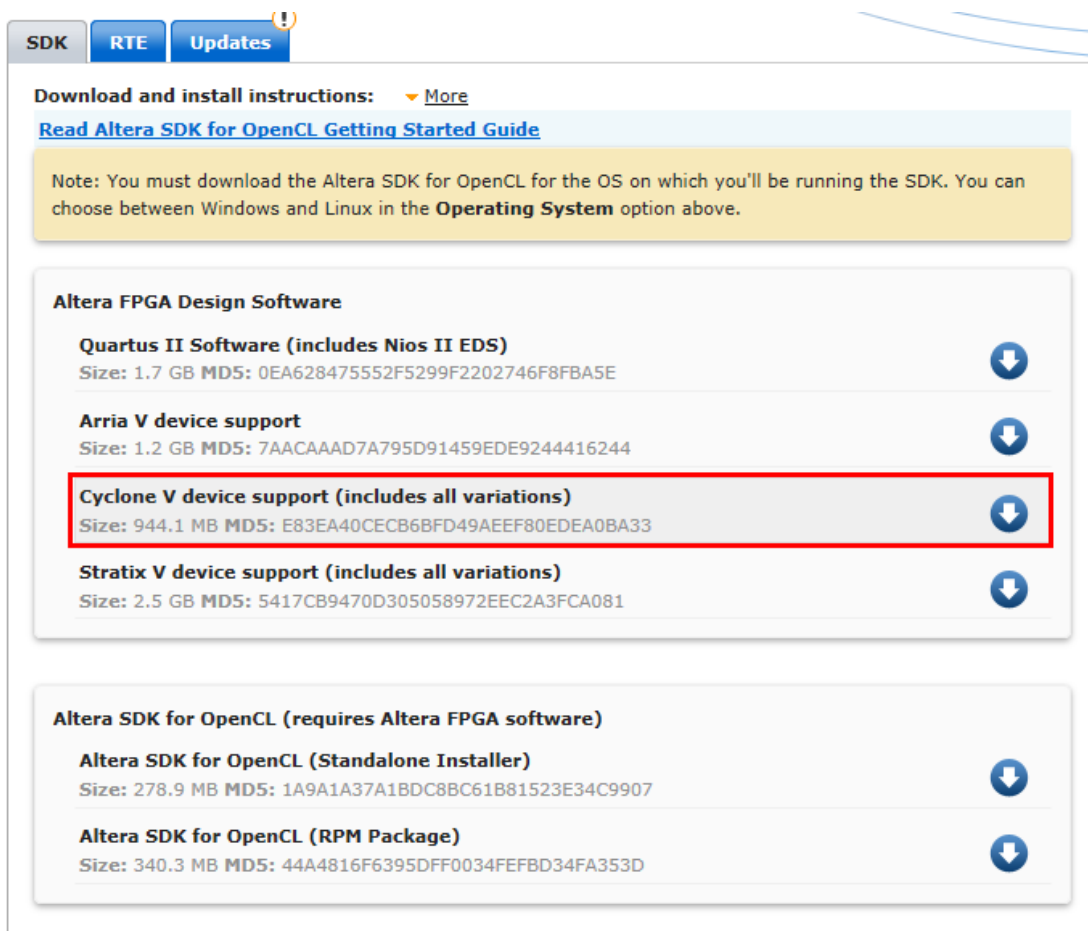
Select release: 14.0

Operating System  Windows  Linux

**Altera® SDK**  
for  
**OpenCL™**

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.



The screenshot shows the 'Downloads' section of the Altera SDK for OpenCL website. It features a navigation bar with 'SDK', 'RTE', and 'Updates' tabs. Below the navigation bar, there are instructions and a note about downloading for the correct OS. The main content area is divided into two sections: 'Altera FPGA Design Software' and 'Altera SDK for OpenCL (requires Altera FPGA software)'. In the 'Altera FPGA Design Software' section, four items are listed with download arrows: 'Quartus II Software (includes Nios II EDS)', 'Arria V device support', 'Cyclone V device support (includes all variations)', and 'Stratix V device support (includes all variations)'. The 'Cyclone V device support' item is highlighted with a red box. In the 'Altera SDK for OpenCL' section, two items are listed: 'Altera SDK for OpenCL (Standalone Installer)' and 'Altera SDK for OpenCL (RPM Package)'. Each item includes its size and MD5 hash.

Item	Size	MD5
Quartus II Software (includes Nios II EDS)	1.7 GB	0EA628475552F5299F2202746F8FBA5E
Arria V device support	1.2 GB	7AACAAAD7A795D91459EDE9244416244
<b>Cyclone V device support (includes all variations)</b>	944.1 MB	E83EA40CECB6BFD49AEFF80EDEA0BA33
Stratix V device support (includes all variations)	2.5 GB	5417CB9470D305058972EEC2A3FCA081
<b>Altera SDK for OpenCL (requires Altera FPGA software)</b>		
Altera SDK for OpenCL (Standalone Installer)	278.9 MB	1A9A1A37A1BDC8BC61B81523E34C9907
Altera SDK for OpenCL (RPM Package)	340.3 MB	44A4816F6395DFF0034FEFBD34FA353D

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**.

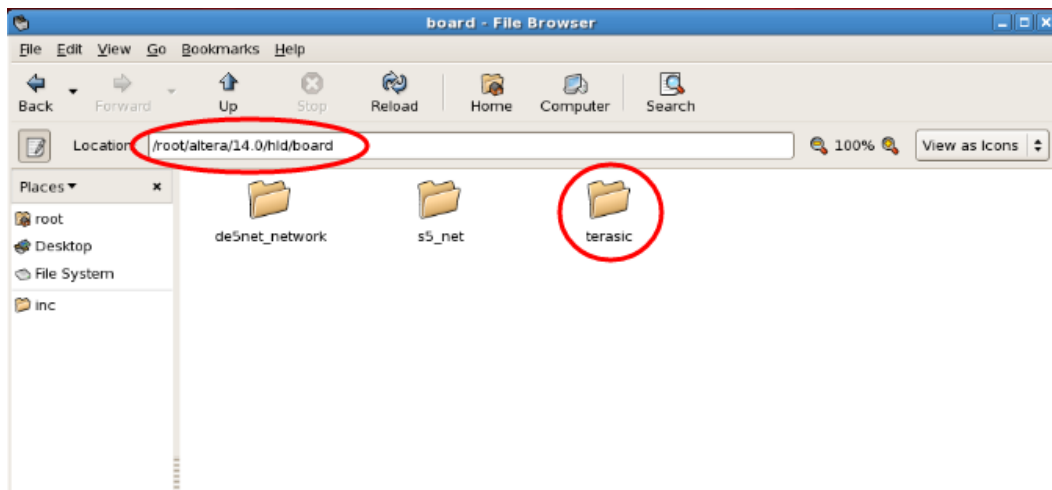


Figure 3-3 Copy the terasic folder to the /root/altera/14.0/hld/bolard folder

## 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
```

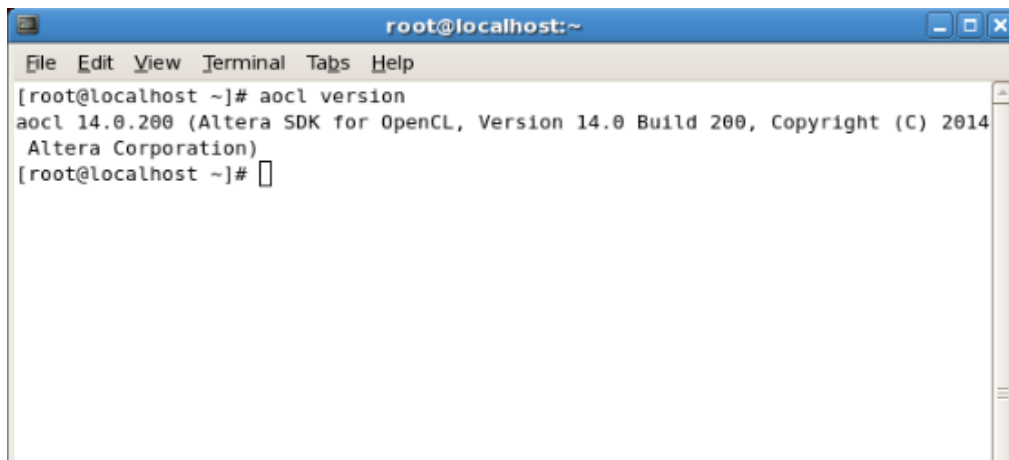
## 3.4 Verification of OpenCL Environment

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

“%ALTEAOCLSDKROOT%\bin” path is added to the **PATH** environment variable correctly.



```
root@localhost:~  
File Edit View Terminal Tabs Help  
[root@localhost ~]# aocl version  
aocl 14.0.200 (Altera SDK for OpenCL, Version 14.0 Build 200, Copyright (C) 2014  
Altera Corporation)  
[root@localhost ~]#
```

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.



```
root@localhost:~  
File Edit View Terminal Tabs Help  
[root@localhost ~]# aoc --list-boards  
Board list:  
  de1soc_sharedonly  
[root@localhost ~]#
```

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**.



```

root@localhost:~
File Edit View Terminal Tabs Help
[root@localhost ~]# echo $AOCL_BOARD_PACKAGE_ROOT
/root/altera/14.0/hld/board/terasic/de1soc
[root@localhost ~]#

```

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 information 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](http://www.altera.com/literature/hb/opencl-sdk/aocl_programming_guide.pdf)

```

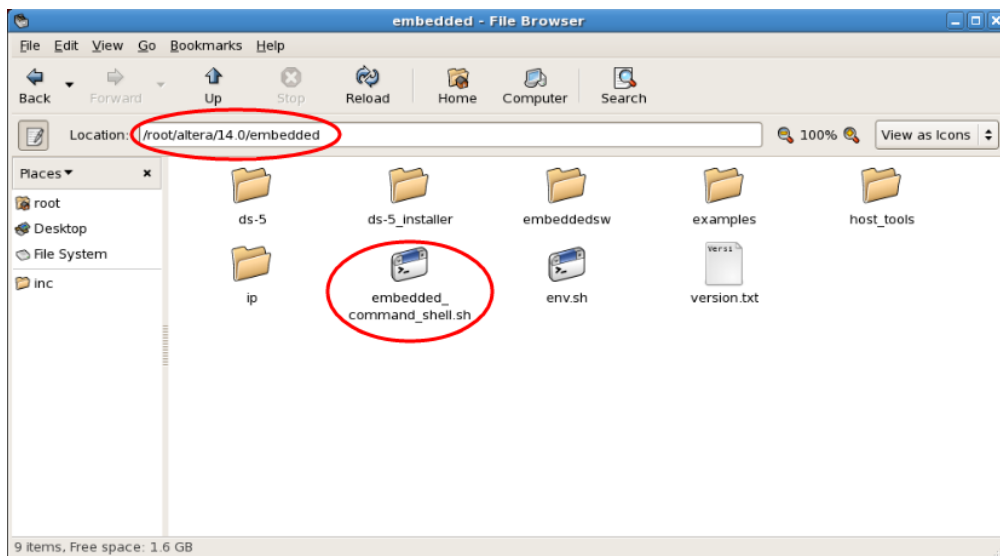
root@localhost:~/altera/14.0/hld/board/terasic/de1soc/examples/boardtest
File Edit View Terminal Tabs Help
1:40:42: warning: declaring kernel argument with no 'restrict' may lead to low k
ernel performance
kclk (__global uint *src, __global uint *dst, uint arg, uint arg2)
      ^
/root/altera/14.0/hld/board/terasic/de1soc/examples/boardtest/device/boardtest.c
1:45:20: warning: declaring kernel argument with no 'restrict' may lead to low k
ernel performance
    __global uint *dst,
      ^
/root/altera/14.0/hld/board/terasic/de1soc/examples/boardtest/device/boardtest.c
1:46:26: warning: declaring kernel argument with no 'restrict' may lead to low k
ernel performance
    __global const uint *index,
      ^
10 warnings generated.
Warning: Unused kernel argument 'arg'
Warning: Unused kernel argument 'arg2'
Warning: Unused kernel argument 'arg'
Warning: Unused kernel argument 'arg2'
Warning: Unused kernel argument 'src'
Warning: Unused kernel argument 'dst'
Warning: Unused kernel argument 'arg'
Warning: Unused kernel argument 'arg2'
[root@localhost boardtest]#

```

**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.

```

root@localhost:~/altera/14.0/hld/board/terasic/de1soc/examples/boardtest
File Edit View Terminal Tabs Help
-----
Altera Embedded Command Shell
Version 14.0
-----
[root@localhost embedded]# cd /root/altera/14.0/hld/board/terasic/de1soc/exampl
s/boardtest
[root@localhost boardtest]# make
arm-linux-gnueabi-g++ -fPIC host/src/main.cpp host/src/memspeed.cpp host/sr
c/reorder.cpp host/src/reorder_ocl.cpp host/src/hostspeed.cpp host/src/hostsp
eed_ocl.cpp host/src/aclutil.cpp host/src/timer.cpp host/src/rwtest.cpp -o bo
ardtest_host -DLINUX -I/root/altera/14.0/hld/host/include -L/root/altera/14.0/h
ld/board/terasic/de1soc/arm32/lib -L/root/altera/14.0/hld/host/arm32/lib -L/root
/altera/14.0/hld/host/arm32/lib -lalteracl -ldl -lacl_emulator_kernel_rt -lalte
rahalmmdd -lalterammdpcie -lelf -lrt -lstdc++
[root@localhost boardtest]#

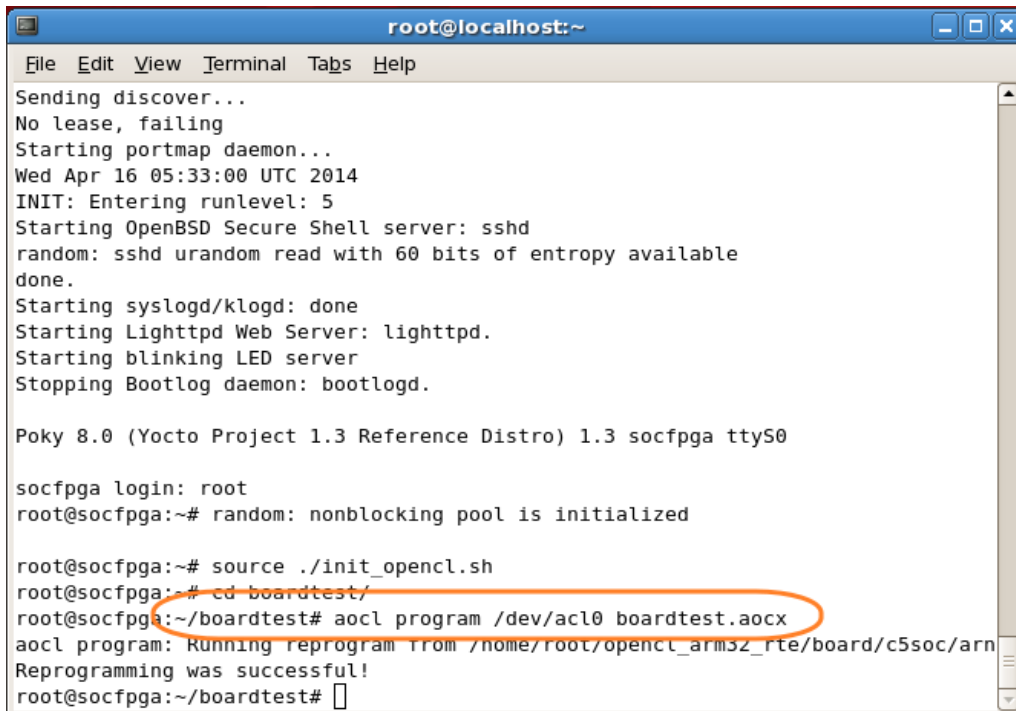
```

**Figure 3-9** Type ‘make’ to build the boardtest host project

- **Test boardtest project**

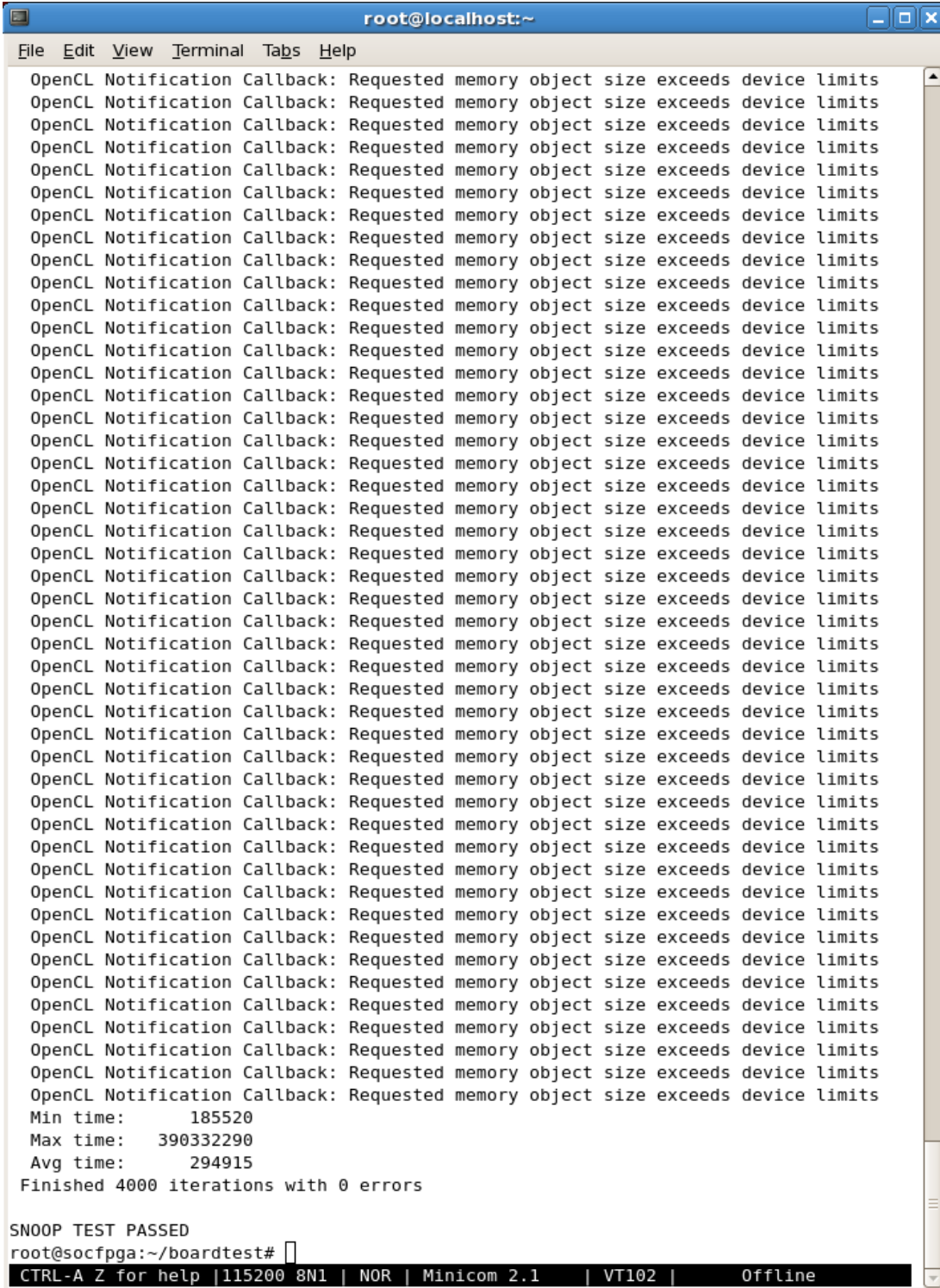
Please boot DE1-SoC with the Linux image for DE1-SoC OpenCL described in Chapter 1.4. Users need to copy the generated kernel file **boardtest.aocx** and the host file **boardtest** from the host PC to the Linux system running on DE1-SoC by establishing SSH connection via Ethernet with “scp” command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



```
root@localhost:~  
File Edit View Terminal Tabs Help  
Sending discover...  
No lease, failing  
Starting portmap daemon...  
Wed Apr 16 05:33:00 UTC 2014  
INIT: Entering runlevel: 5  
Starting OpenBSD Secure Shell server: sshd  
random: sshd urandom read with 60 bits of entropy available  
done.  
Starting syslogd/klogd: done  
Starting Lighttpd Web Server: lighttpd.  
Starting blinking LED server  
Stopping Bootlog daemon: bootlogd.  
  
Poky 8.0 (Yocto Project 1.3 Reference Distro) 1.3 socfpga ttyS0  
  
socfpga login: root  
root@socfpga:~# random: nonblocking pool is initialized  
  
root@socfpga:~# source ./init_openc1.sh  
root@socfpga:~# cd boardtest/  
root@socfpga:~/boardtest# aocl program /dev/acl0 boardtest.aocx  
aocl program: Running reprogram from /home/root/openc1_arm32_rte/board/c5soc/arm  
Reprogramming was successful!  
root@socfpga:~/boardtest#
```

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



```

root@localhost:~
File Edit View Terminal Tabs Help
OpenCL Notification Callback: Requested memory object size exceeds device limits
OpenCL Notification Callback: Requested memory object size exceeds device limits
OpenCL Notification Callback: Requested memory object size exceeds device limits
OpenCL Notification Callback: Requested memory object size exceeds device limits
OpenCL Notification Callback: Requested memory object size exceeds device limits
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OpenCL Notification Callback: Requested memory object size exceeds device limits
OpenCL Notification Callback: Requested memory object size exceeds device limits
OpenCL Notification Callback: Requested memory object size exceeds device limits
OpenCL Notification Callback: Requested memory object size exceeds device limits
Min time:      185520
Max time:     390332290
Avg time:      294915
Finished 4000 iterations with 0 errors

SNOOP TEST PASSED
root@socfpga:~/boardtest#
CTRL-A Z for help |115200 8N1 | NOR | Minicom 2.1 | VT102 | Offline
  
```

Figure 3-11 “boardtest” test is successful