Introduction
# Revision History

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<td>03/09/17</td>
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<td>Tutorial validated for SDx™ IDE 2016.4.</td>
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<td>Initial documentation release for SDx IDE 2016.3, which includes both the SDSoC™ Environment and the SDAccel™ Environment. Due to this major change in tool architecture, this document has undergone substantial changes in structure and content since the previous release.</td>
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Introduction

The Xilinx SDAccel™ Development Environment is part of the SDx Development Toolchain. This toolchain allows you to create FPGA accelerated designs using C/C++ programming languages. You can create these designs in the SDx GUI environment or through a Makefile flow.

This tutorial walks you through the steps of building a basic OpenCL™ based design using the SDx GUI and learning some of the features that enable you to do performance profiling, and optimization.

Tutorial Design Description

This tutorial is based on the Smith-Waterman algorithm, which is a database search algorithm developed by T.F. Smith and M.S. Waterman. It is based on the earlier Needleman and Wunsch algorithm.

The design targets the Alpha Data Kintex® Ultrascale™ PCIe® board utilizing the xcku060 device.

TIP: Although this tutorial design targets a xcku060 Kintex Ultrascale board, you can choose any other board, such as the xc7k690t Kintex-7 board. Tutorial results should be similar.

Hardware and Software Requirements

Refer to the Vivado Design Suite User Guide: Release Notes, Installation, and Licensing, (UG973) for a complete list and description of the system and software requirements for the Vivado® Design Suite.

Locating Tutorial Design Files

You can find the files for this tutorial in the SDx Suite examples directory at the following location:

<SDx_install_area>/<version>/examples

NOTE: SDAccel is only available on Linux operating systems that support the GLIBC 2.9 or higher compiled library.
Flow Overview

Lab 1: Introduction to the SDAccel Development Environment

Step 1: Creating SDAccel Project

1. Launch SDx with the command `sdx` and you will see the **Workspace Launcher** window. Select a location for your workspace, this is where the project will reside.

   *Figure 1: Workspace Launcher*

2. In the the **SDx Welcome** window, click **Create SDx Project**.
3. In the **Create a New SDx project** window in the **Project name** field, type *smithwaterman* and click **Next**.

4. In the **Choose Hardware Platform** window choose the **ADM-PCIE-KU3 (2ddr)** platform and click **Next**.
5. The **Software Platform** window will only have *Linux on x86* as a valid option, click **Next**.

6. The **Templates** window has a list of possible templates that you can use to get started in building an SDAccel project. For this tutorial, select **Empty Application** and click **Finish**.
Step 2: Importing Design Files

1. In the **Project Explorer** window, expand **smithwaterman > src**. Right-click **src** and select **Import**.
2. In the Import dialog box, under General, select File System, and click Next.
3. In the **Import** dialog and text box labeled **From directory**, navigate to the **getting_started** directory from the install directory (<install location>/examples), and select the **src** directory. Click **OK**.

4. In the **Import** dialog box, select the following files:
   - `kernel.cl`
   - `main.cpp`
   - `oclErrorCodes.cpp`
   - `oclHelper.cpp`
   - `oclHelper.h`
   - `soft.cpp`
   
   Click **Finish**.
5. You can now expand the `src` directory to see that all the files are now populated in the project.
Step 3: Running CPU Emulation

This step shows you how to run CPU Emulation of a design, by setting Run Configuration settings, opening reports, and showing how to launch Debug. Details on reports and Debug can be found in the SDAccel Environment User Guide, (UG1023).

1. To run CPU Emulation, go to SDx Project Settings and ensure that Active build configuration is set to Emulation-CPU.

   **Figure 8: SDx Project Settings**

2. Create an accelerator that will be the container for the kernel found in kernel.cl. In this view, click the lightning bolt button: ⚡️. SDx analyzes the design for all possible kernels in the design (as well as the ability to filter the list if there are multiple kernels). For this design, only the **smithwaterman** exists. Ensure that the function name **smithwaterman** is selected and click OK. This creates a binary container for the kernel, which can be renamed if necessary.
3. Click the Green Arrow: to run CPU Emulation. This builds the project before running the emulation.

4. Take note that the design successfully builds, but the emulation test fails. This can be viewed by looking for FAILED TEST in the Console window. Look at the main.cpp and notice that there are arguments that need to be provided. The Run Configurations field need to be adjusted to account for these arguments.

5. Go to the Run menu and to Run Configurations...
6. Under the **Arguments** tab we see only the container that holds the kernel as an argument. For this design, the following arguments need to be adjusted:

   ```
   -d acc -k ../binary_container_1.xclbin -i 2 -l -1
   ```

   - **-d**, Is to say what type of device it is. In this case, `acc` specifies an accelerator.
   - **-k**, Is to specify the kernel to use. If `-d` is set to `acc` then this must be a binary file.
   - **-i**, The number of iterations to run.
   - **-l**, The sequence length to be used in the algorithm. `-1` specifies the default length.

   (To view more information about the argument list, use `-h` for the executable to see an entire list) Click **Run**.

   **Figure 10: Run Configuration**

7. The **Console** winow should show **PASSED TEST**. If you want to see a verbose output of what the algorithm is doing, go back into **Run Configurations...** and add the `-v` to the arguments.
8. After the emulation run is complete, you can look at two reports to design details for further optimization. In the Reports window, double click Profile Summary. Here, you can view operations, execution time, bandwidth, and other useful data that can be used to optimize the design. Do note that the summary numbers may vary.

**Figure 11: Emulation-CPU Profile Summary**

![Emulation-CPU Profile Summary](image)

9. To view the Application Timeline report, in the Reports window, double click Application Timeline. This shows a breakdown of the host code and the kernel code, and execution time for each.

**Figure 12: Application Timeline Report**

![Application Timeline Report](image)
10. From the **Profile Summary** and the **Application Timeline** you can see issues in how the host and kernel communicate with each other. Using the **Debug** feature can help pinpoint these issues.

11. To run in Debug, a breakpoint needs to be set. Setting breakpoints at key points in the execution helps identify problems. From the **Application Timeline**, notice that the API Calls are staggered around the end of the timeline. If you zoom in by clicking and dragging the mouse near the end of the timeline, you can see the fluctuation more easily. Hovering the mouse over the **Queue** line over the green boxes, you will notice that the tooltip shows that `clEnqueueReadBuffer` is being called several times. Set a breakpoint at the main for loop in `main.cpp` (line 396) by right-clicking the line number on the line and selecting **Toggle Breakpoint**. This is the iteration loop where `clEnqueueReadBuffer` is executed in the code.

**Figure 13: Setting Breakpoint**

12. To run **Debug**, click on this icon: 📊. A dialog box opens up asking you to switch to that perspective. Click **Yes**.

13. Using Eclipse debugging, the host and kernel code can be examined in more detail. All the controls with which to do step-by-step debugging are in the **Run** menu.
14. After you start, Debug stops at line 441. This is the first line of `main` to be executed. In the **Runs Configuration** dialog, there is an option to stop on the `main` function (see the following figure). This is helpful in case of a problematic function in need of more thorough debugging. Press **F8** to continue to the next breakpoint.
15. The debugger is now at the for loop where you set the breakpoint. The run was configured to go through two iterations. Step through the loop while looking at the Variables window, and see the variables changing as the stepping occurs.

16. Close the Debug Perspective by going to the upper-right of the window where it shows Debug, right-click and select Close.

**Step 4: Running Hardware Emulation**

This step will cover running hardware emulation feature as well as looking at the basics of profiling and reports.

1. To run Hardware Emulation, go to SDx Project Settings and make sure that Active build configuration is set to Emulation-HW then click Run. This will take some time to complete.

**NOTE:** The main difference between Emulation-CPU and Emulation-HW is that emulating hardware builds a design that is closer to what is seen on the platform. This means data related to bandwidth, throughput, and execution time are more accurate. The design also takes longer to compile.
2. In the **Reports** tab, open **System Estimate**. This is a text report that provides information related to kernel information, timing about the design, clock cycles, and area used in the device.

   **Figure 16: System Estimate**

![System Estimate](image1)

3. In the **Reports** tab, open **Profile Summary**. This summary report provides detailed information related to kernel operation, data transfers, and OpenCL™ API calls as well as profiling information related to the resource usage, and data transfer to/from the kernel/host. It also provides detailed guidance in how to meet the profile rule checks.

   **Figure 17: Profile Summary Report**

![Profile Summary](image2)
4. Scroll to the right in the **Profile Rule Checks** and look for the header column labeled **Guidance**. Here is where unmet checks provide some information on how to optimize the kernel.

**Figure 18: Profile Rule Checks**

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**NOTE:** To see other performance optimization techniques and methodologies, please go to the SDAccel Performance Optimization Methodology Guide ([UG1207](#)).

5. Open the **Application Timeline** report. This report shows the estimated time it takes for the host and kernel to complete the task and provides finer grained information on where bottlenecks can be. In this example, it is iterated twice and this timeline shows the kernel is run twice. Adding a marker, zooming, and expanding signals can help in identifying bottlenecks.
6. Open the **HLS Report**. This report provides detailed information provided by Vivado® HLS on the kernel transformation and synthesis. The tabs at the bottom provide more information on where most of the time is spent in the kernel and other performance related data. Some performance data may be latency and clock period.

**Figure 20: HLS Report**
Step 5: Makefile Flow

This step explains the basics of the Makefile flow and how SDx uses it. The advantages to using this flow include the following

- Easy automation into any system.
- Faster turnaround time on small design changes.

1. In the Project Explorer, navigate to the Emulation-CPU directory and look for the makefile file. Double-click the file to open it in the editor. This is the makefile that SDx creates and uses for building and running emulations.

2. In the Project Explorer, navigate to the Emulation-HW directory and look for the makefile file. Open the file.

3. While the project is building, go back into the makefile editor window and look at line 19 in both files. Notice that each one is set to either hw_emu or sw_emu.

**Figure 21: Makefile Editor window**

4. The makefile can also access SDx without using the GUI. Open up a new terminal session and navigate to where the workspace and navigate to the Emulation-CPU directory and type: make incremental. The process will produce a typical SDx log output.
Summary

After completing this tutorial, you should be able to do the following:

• Create an SDAccel™ project and import the required design files.
• Create a binary container and accelerator for the design.
• Run CPU Emulation and use the Debug environment on host and kernel code.
• Run Hardware Emulation and use the reports to understand possible optimization.
• Understand differences between CPU and Hardware Emulation reports.
• Read the project makefile and run the makefile command line.
Additional Resources and Legal Notices

Xilinx Resources

For support resources such as Answers, Documentation, Downloads, and Forums, see Xilinx Support.

Solution Centers

See the Xilinx Solution Centers for support on devices, software tools, and intellectual property at all stages of the design cycle. Topics include design assistance, advisories, and troubleshooting tips.

References

1. *SDx Environments Release Notes, Installation, and Licensing Guide* (UG1238)
6. *SDAccel Development Environment web page*
7. *Vivado® Design Suite Documentation*
10. *Khronos Group web page*: Documentation for the OpenCL standard
11. *Alpha Data web page*: Documentation for the ADM-PCIE-7V3 Card
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