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Designing a System Using the Aurora 8B/10B Core (Simplex) on the KC705 Evaluation Kit

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Summary

This application note explains the steps required to validate the Xilinx LogiCORE™ Aurora 8B/10B IP core on the Kintex®-7 FPGA KC705 Evaluation Kit. Aurora 8B/10B is a scalable, lightweight, high data rate, link-layer protocol for high-speed serial communication. Aurora is designed to enable easy implementation of Xilinx transceivers using an intuitive wizard interface. The Aurora protocol specification is open and available upon request. The Aurora core is available free of charge in the Vivado® IP catalog and is licensed for use with Xilinx silicon devices.

Aurora is typically used in applications where other industry standard serial interfaces are either too complex or resource intensive. Aurora delivers a low-cost, high data rate, scalable and flexible means to build a serial data channel. Its simple framing structure can be used to encapsulate data from existing protocols, and electrical requirements are compatible with commodity equipment. Aurora can be used to provide increased performance without high FPGA resource costs, software redevelopment, or exotic physical infrastructure.

The reference design is targeted for the Xilinx Kintex-7 FPGA KC705 evaluation board.

Included Systems

The reference design is created and built using the Vivado Design Suite: System Edition 2014.1. The Vivado Design Suite helps simplify the task of instantiating, configuring, and connecting IP blocks to form complex integrated systems. The design also includes VIO and ILA cores to probe the signals.

Introduction

This application note details the steps required to configure the Aurora 8B/10B core with Vivado Design Suite and to validate the operation of the core in simplex mode using the VIO and ILA cores to probe various signals.

The example presented is a single-lane simplex configuration using two platforms (see Figure 1). The completed example design can be used to form a building block for more complex systems.

The example test setup uses two clock sources to generate the 156.25 MHz clock signals. *Any suitable conditioned 156.25 MHz clock source can be used to replicate these examples.*

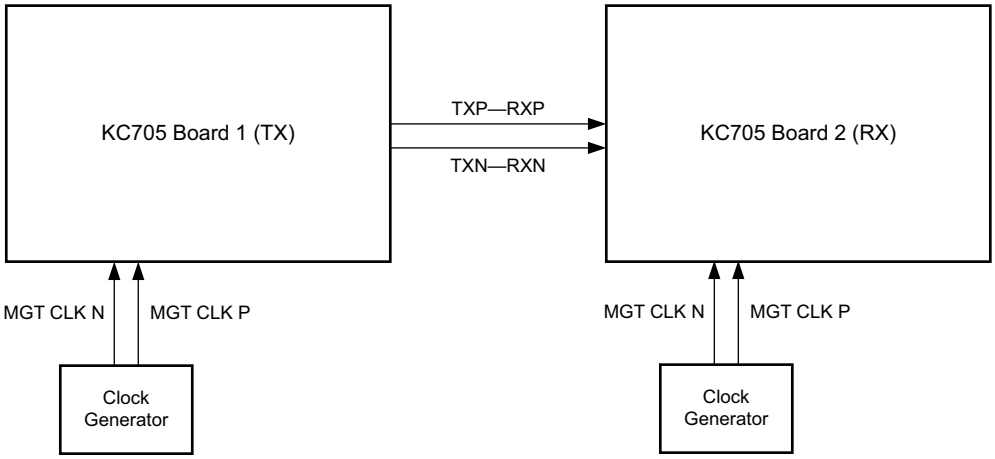

Figure 1: **Simplex Reference Design**

Hardware Requirements

The single-lane simplex configuration requires these hardware components:

- Two Kintex-7 FPGA KC705 evaluation boards
- Two KC705 Universal 12v power adapters
- Two suitable clock generators to generate 156.25 MHz
- Two JTAG platform USB cables
- Four SMA to SMA connector cables (for reference clock)
- Two SMA to SMA connector cables (for serial data)
- HPC-HPC Samtec cable (for back channel testing with sideband mode)

Software Requirements

Software requirements for the Aurora 8B/10B simplex example design:

- Vivado Design Suite 2014.1

Building Hardware

Simplex Example Design

Customizing the Aurora Core

Follow these steps to customize and generate the Aurora 8B/10B core for the simplex example design:

1. Launch Vivado Design Suite.
2. Select **Create New Project** and click **Next** (Figure 2).

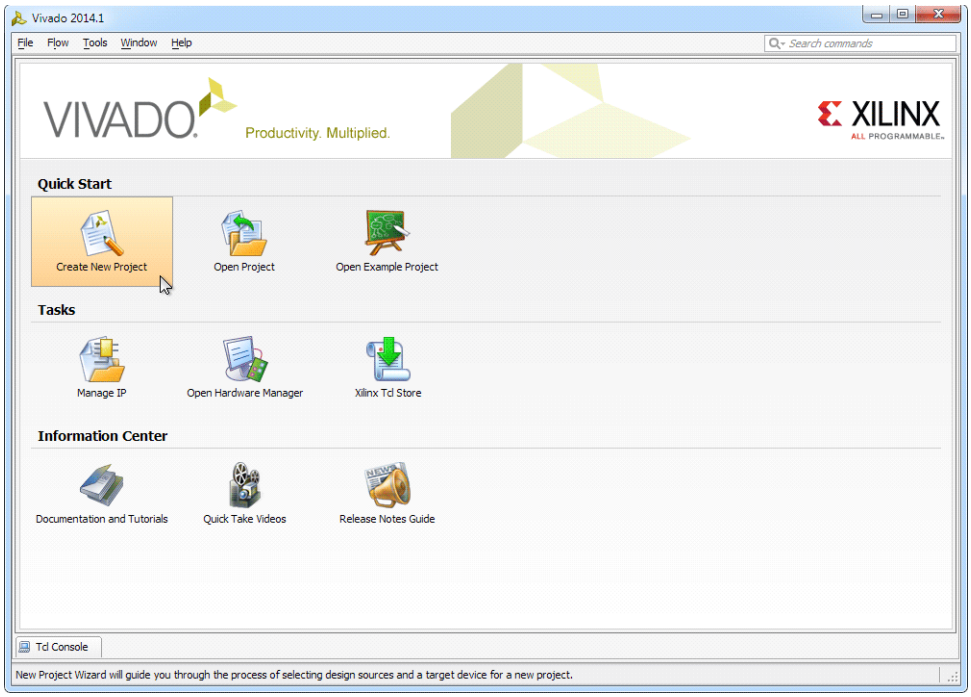

Figure 2: **Create New Vivado Project**

3. Select the project name and path and click **Next** (Figure 3).

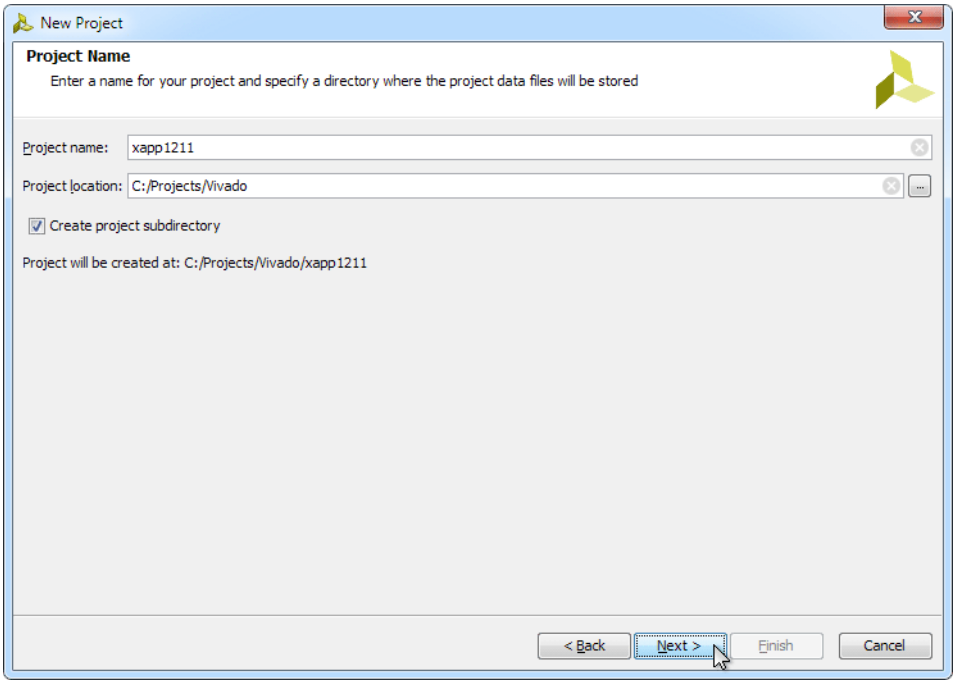

Figure 3: **New Project Name**

4. Select **RTL Project** to permit running the example design and check **Do not specify sources at this time** (Figure 4). Click **Next**.

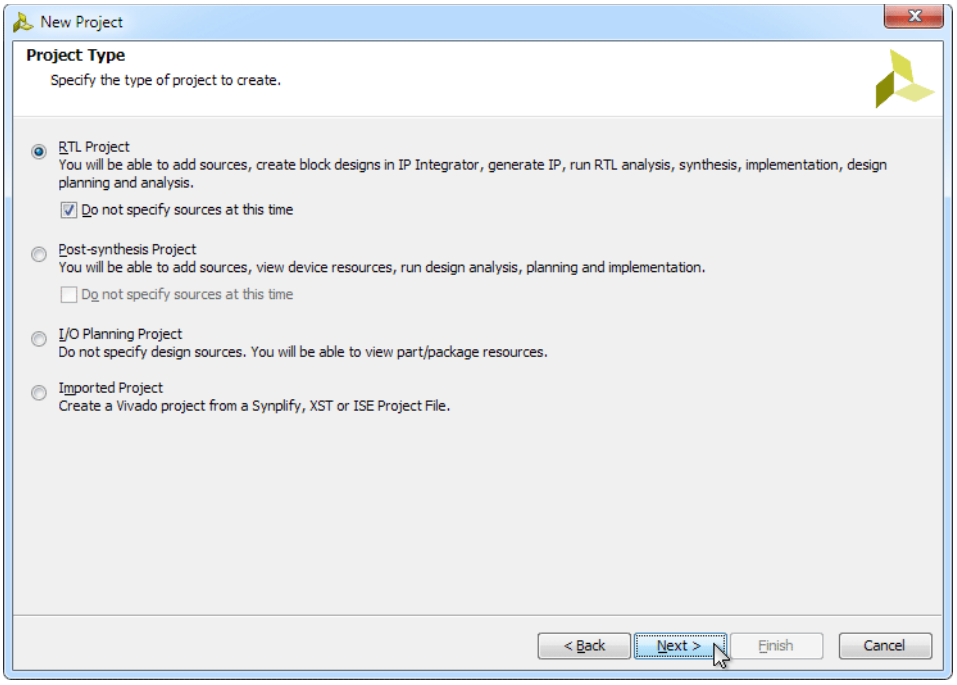

Figure 4: **New Project Type**

5. Click **xc7k325tffg900-2** or, select the **Boards** option and then click **Kintex-7 KC705 Evaluation platform** (Figure 5).

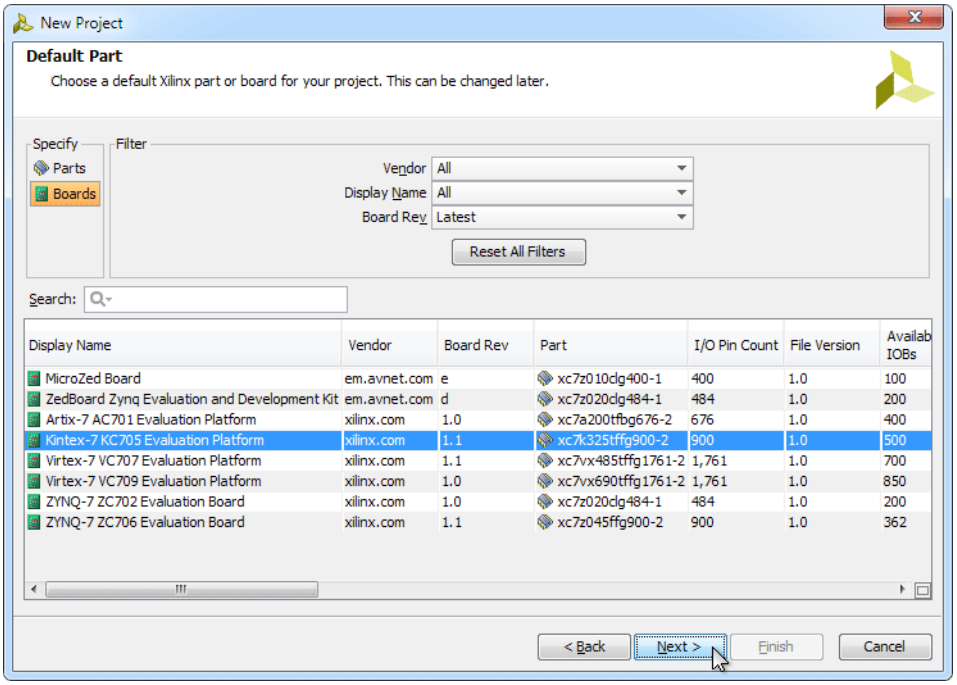

Figure 5: **New Project Default Part**

6. Click **Next**, then click **Finish**.
7. Under Project Manager in the Flow Navigator panel, select **IP catalog** and search for **Aurora 8B10B**. The Aurora cores can be found under **Communication & Networking > Serial Interfaces** (Figure 6).

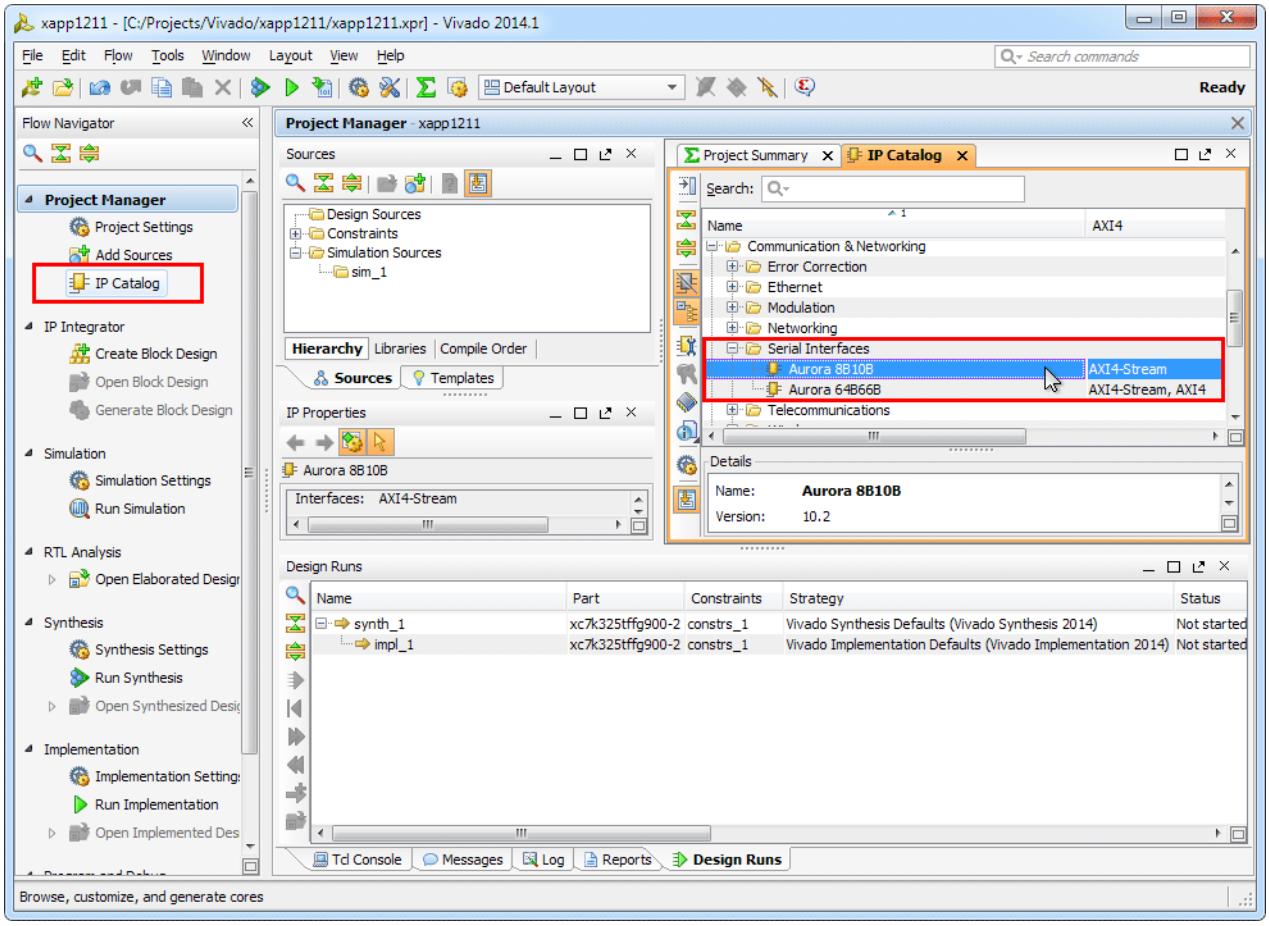

Figure 6: **Aurora 8B/10B Core in IP Catalog**

8. Right-click **Aurora 8B10B** and select **Customize IP** (Figure 7).

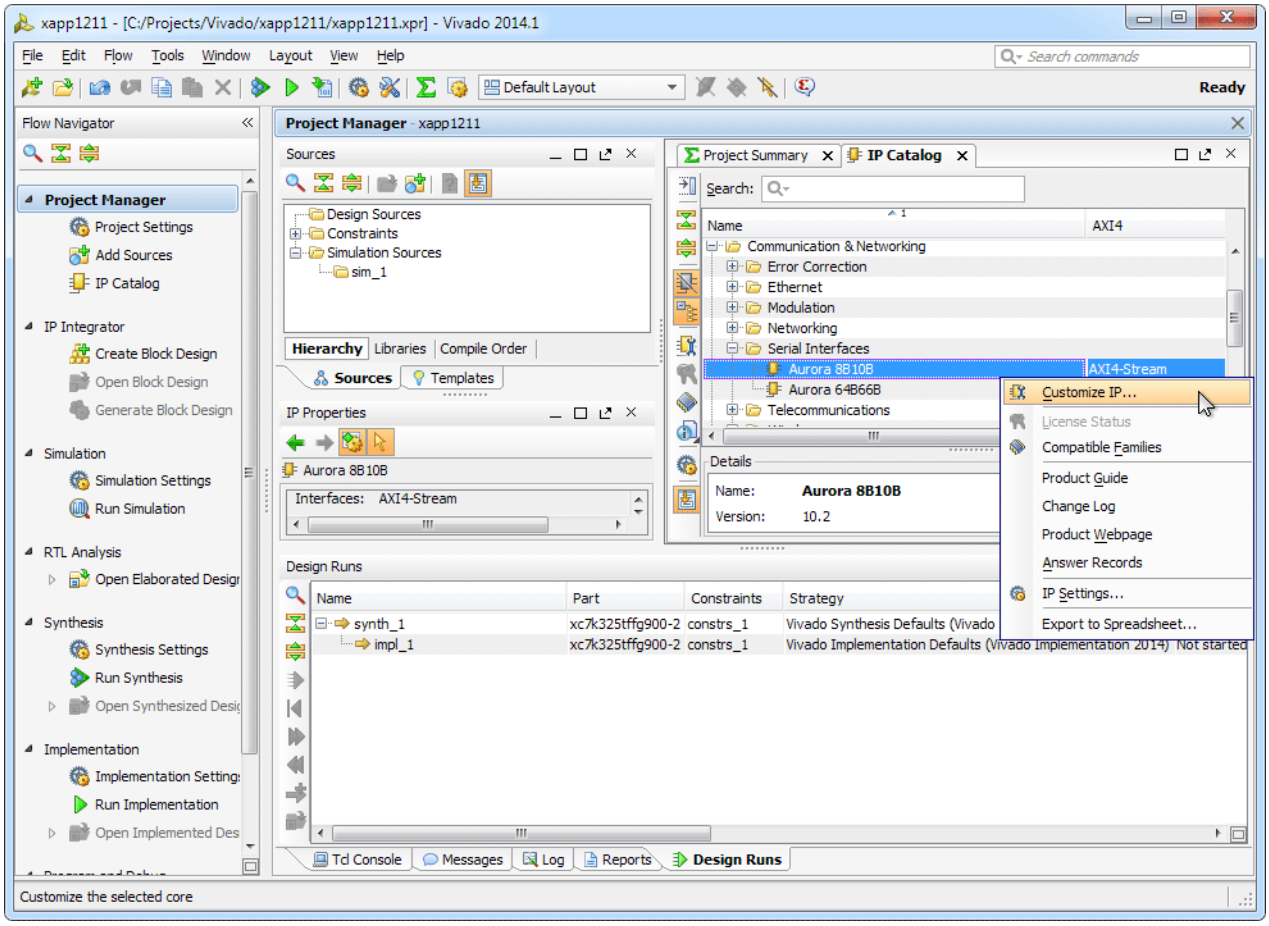

Figure 7: **Customize IP**

9. In the **Core Options** tab of the Customize IP window, set these options (see Figure 8):
   - Set **GT Refclk (MHz)** to **156.25**
   - Set **Dataflow Mode** to **TX-only Simplex** or **RX-only Simplex**, depending on the platform being configured
   - Set **Back Channel** to **Timer** or **Sideband** depending on the desired testing mode.
   - Select the **Vivado Lab Tools** option.

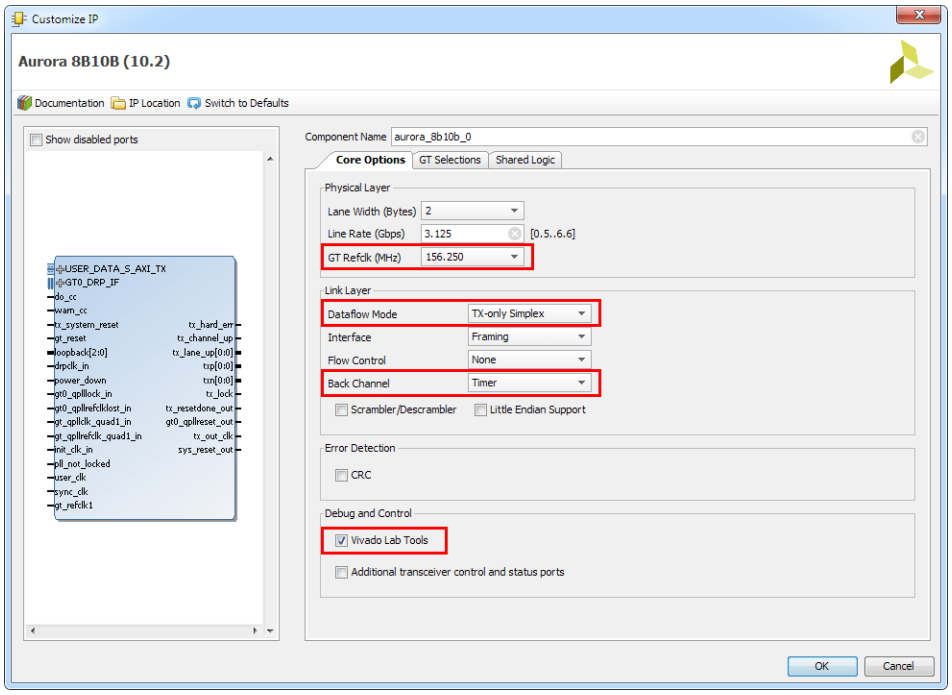

Figure 8: **Aurora 8B/10B Simplex Core Options Settings**

10. Click the **GT Selections** tab.
11. Change the default setting in the lower list box for GTXQ0 from **1** to **X**.
12. Change the lower list box setting for GTXQ2 from **X** to **1** (Figure 9).

Note: The GTXQ2 transceiver is the only transceiver pinned out to SMA connectors on the KC705 board. When placing the cursor over the list box setting, a tooltip appears to verify the location of the selected transceiver.

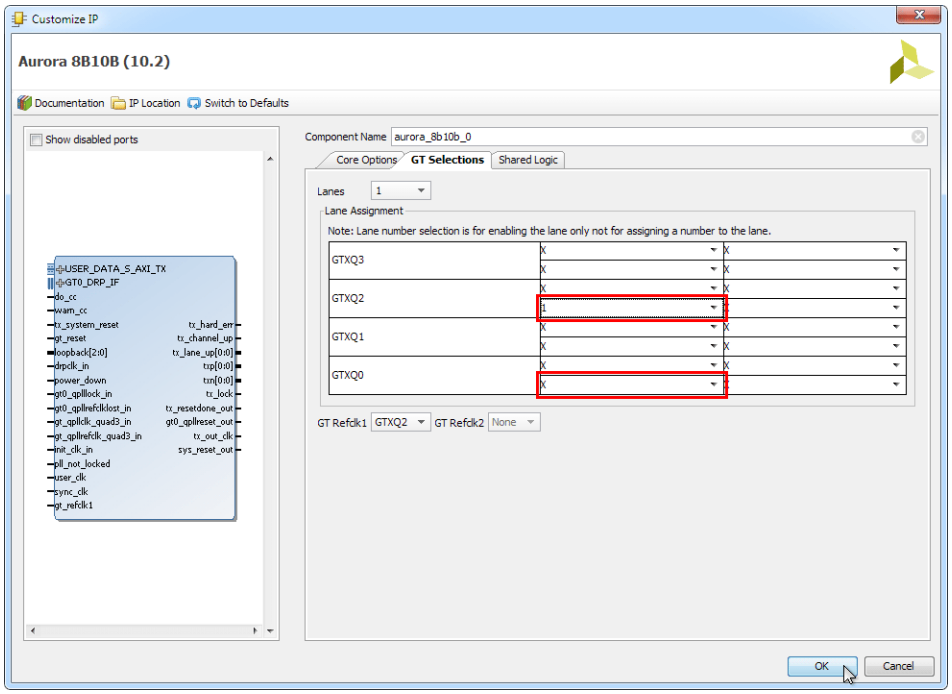

Figure 9: **Aurora 8B/10B Simplex GT Selections**

13. Options on the **Shared Logic** tab should remain at default values. Click **OK**.
14. In the Generate Output Products window, click **Generate**.

Synthesizing the Example Design

1. When product generation is complete, in the Project Manager section of the Vivado IDE, right-click the core name and select **Open IP Example Design** (see Figure 10).

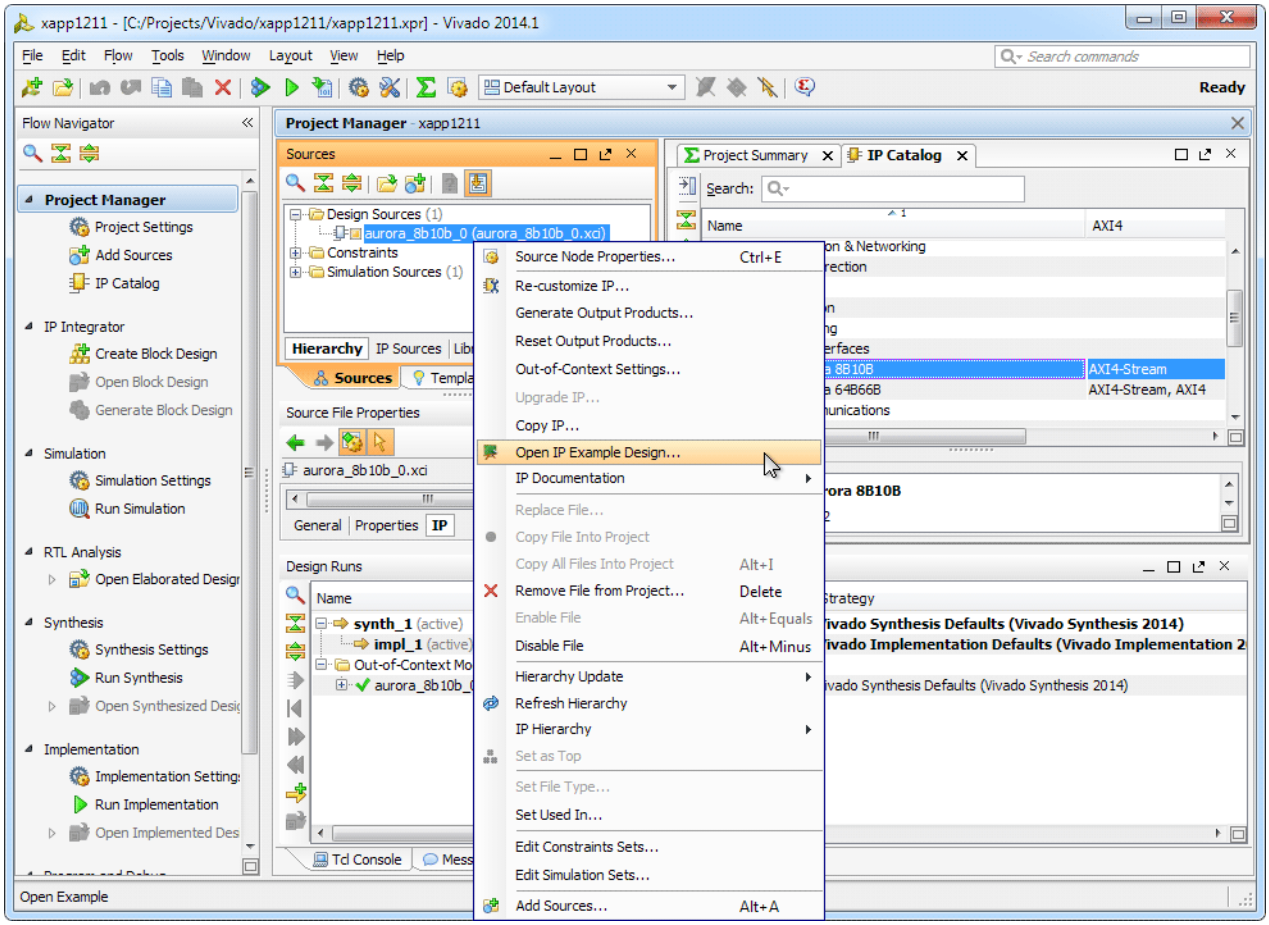

Figure 10: **Open IP Example Design**

2. Click **OK** to overwrite the existing example design.
3. In the newly-opened Vivado IDE window, expand the Constraints entry in the Sources panel of the Project Manager section.
4. Right-click the constraints file (aurora_8b10b_0_exdes.xdc) and select **Open file** (Figure 11).

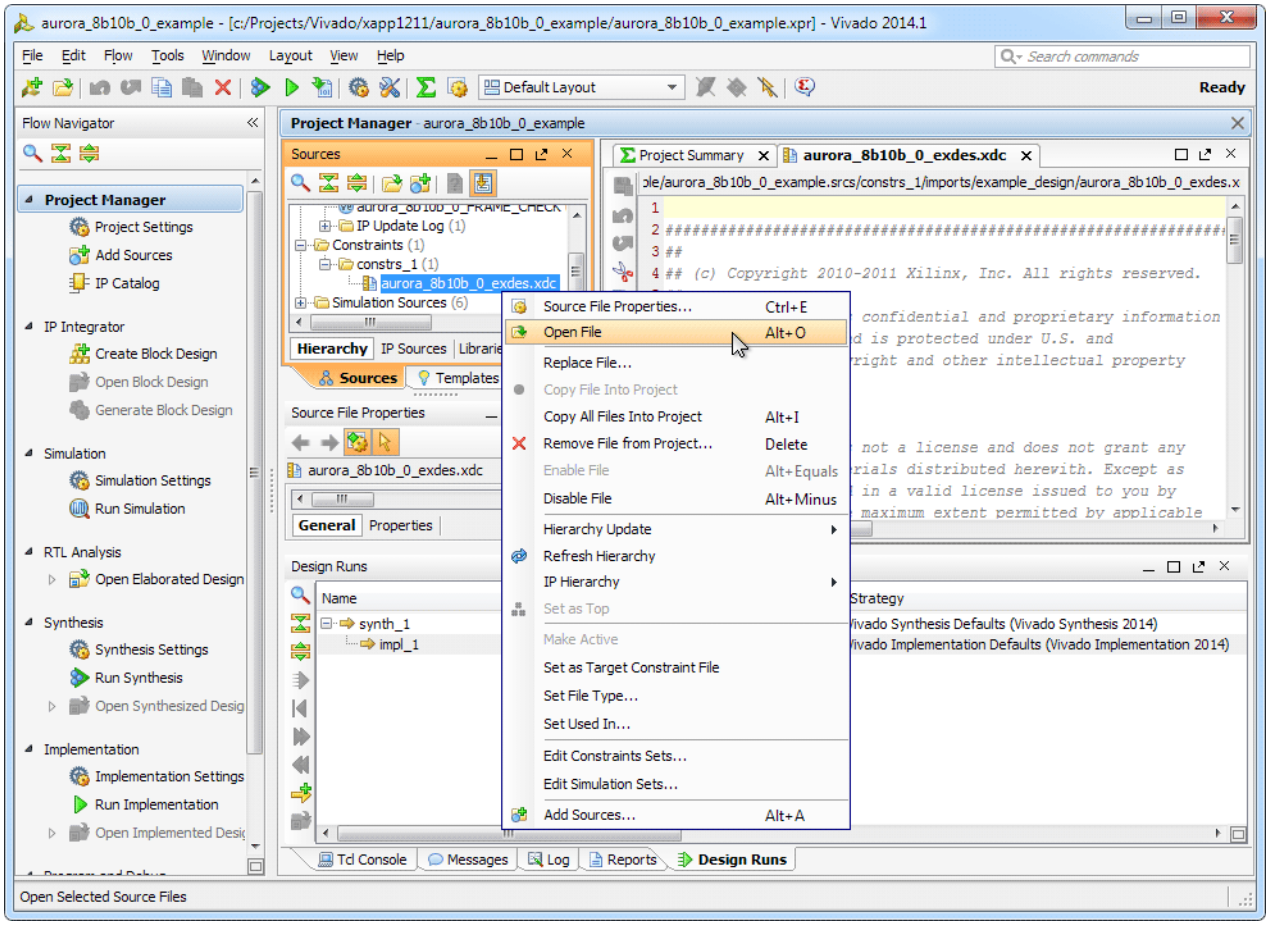

Figure 11: **Open Constraints File**

5. Locate these two LOC property statements in the constraints file:

```
set_property LOC G7 [get_ports GTXQ2_N]
set_property LOC G8 [get_ports GTXQ2_P]
```

6. Referring to Table 1, replace the two LOC property statements with the following nine statements for the respective platform (see Figure 12):

   Transmit Platform:

```
set_property LOC J7 [get_ports GTXQ2_N]
set_property LOC J8 [get_ports GTXQ2_P]
set_property PACKAGE_PIN AD11 [get_ports INIT_CLK_N]
set_property PACKAGE_PIN AD12 [get_ports INIT_CLK_P]
set_property LOC AG5 [get_ports RESET]
set_property LOC AC6 [get_ports GT_RESET_IN]
set_property LOC AA8 [get_ports TX_CHANNEL_UP]
set_property LOC AB8 [get_ports TX_LANE_UP]
set_property LOC B17 [get_ports TX_HARD_ERR]
```

Receive Platform:

```
set_property LOC J7 [get_ports GTXQ2_N]
set_property LOC J8 [get_ports GTXQ2_P]
set_property PACKAGE_PIN AD11 [get_ports INIT_CLK_N]
set_property PACKAGE_PIN AD12 [get_ports INIT_CLK_P]
set_property LOC AG5 [get_ports RESET]
set_property LOC AC6 [get_ports GT_RESET_IN]
set_property LOC AA8 [get_ports RX_CHANNEL_UP]
set_property LOC AB8 [get_ports RX_LANE_UP]
set_property LOC B17 [get_ports RX_HARD_ERR]
```

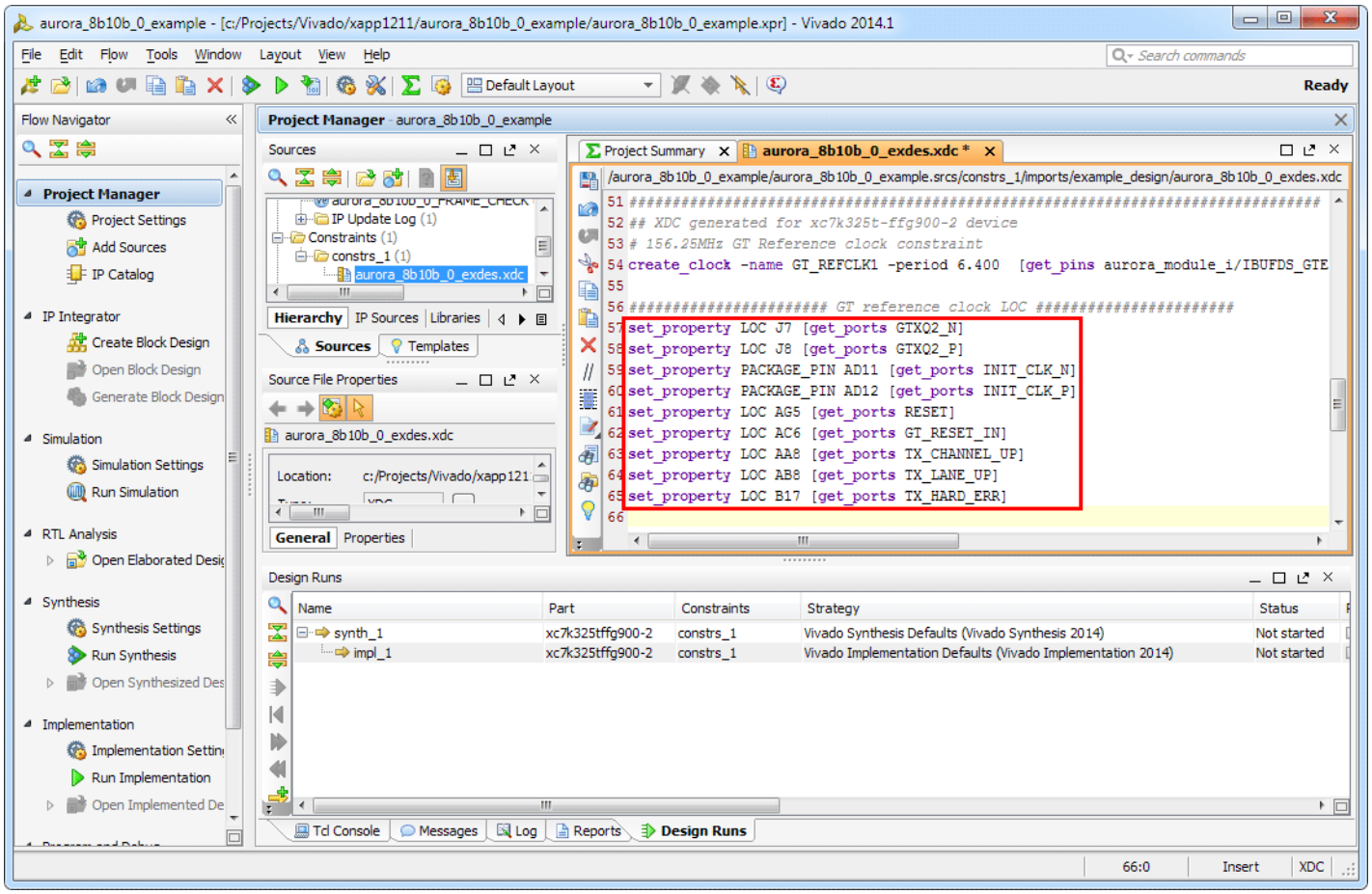

Figure 12: **Simplex LOC Constraints**

Table 1: **Aurora 8B/10B Simplex Constraints**

Pin Name	Loc Value
INIT_CLK_N	AD11
INIT_CLK_P	AD12
RESET	AG5
GT_RESET_IN	AC6
TX_CHANNEL_UP/RX_CHANNEL_UP	AA8
TX_LANE_UP/RX_LANE_UP	AB8
GTXQ2_N	J7
GTXQ2_P	J8
TX_HARD_ERR/RX_HARD_ERR	B17
TX_ALIGNED/RX_ALIGNED(1)	C12
TX_VERIFY/RX_VERIFY(1)	B12
TX_RESET/RX_RESET(1)	C11

Notes:
1. These pins are for back channel testing with sideband mode only.

7. If **Sideband** was selected for **Back Channel** in step 9, page 6, add these three lines to the constraints file for the respective platform:

   Transmit platform:

   ```
   set_property LOC C12 [get_ports TX_ALIGNED]
   set_property LOC B12 [get_ports TX_VERIFY]
   set_property LOC C11 [get_ports TX_RESET]
   ```

   Receive platform:

   ```
   set_property LOC C12 [get_ports RX_ALIGNED]
   set_property LOC B12 [get_ports RX_VERIFY]
   set_property LOC C11 [get_ports RX_RESET]
   ```

8. Locate the `init_clk_i` setting in the constraints file.
9. Change the comment from **50 MHz** to **200 MHz**.
10. Change the period from **20.000** to **5.000** (see Figure 13).

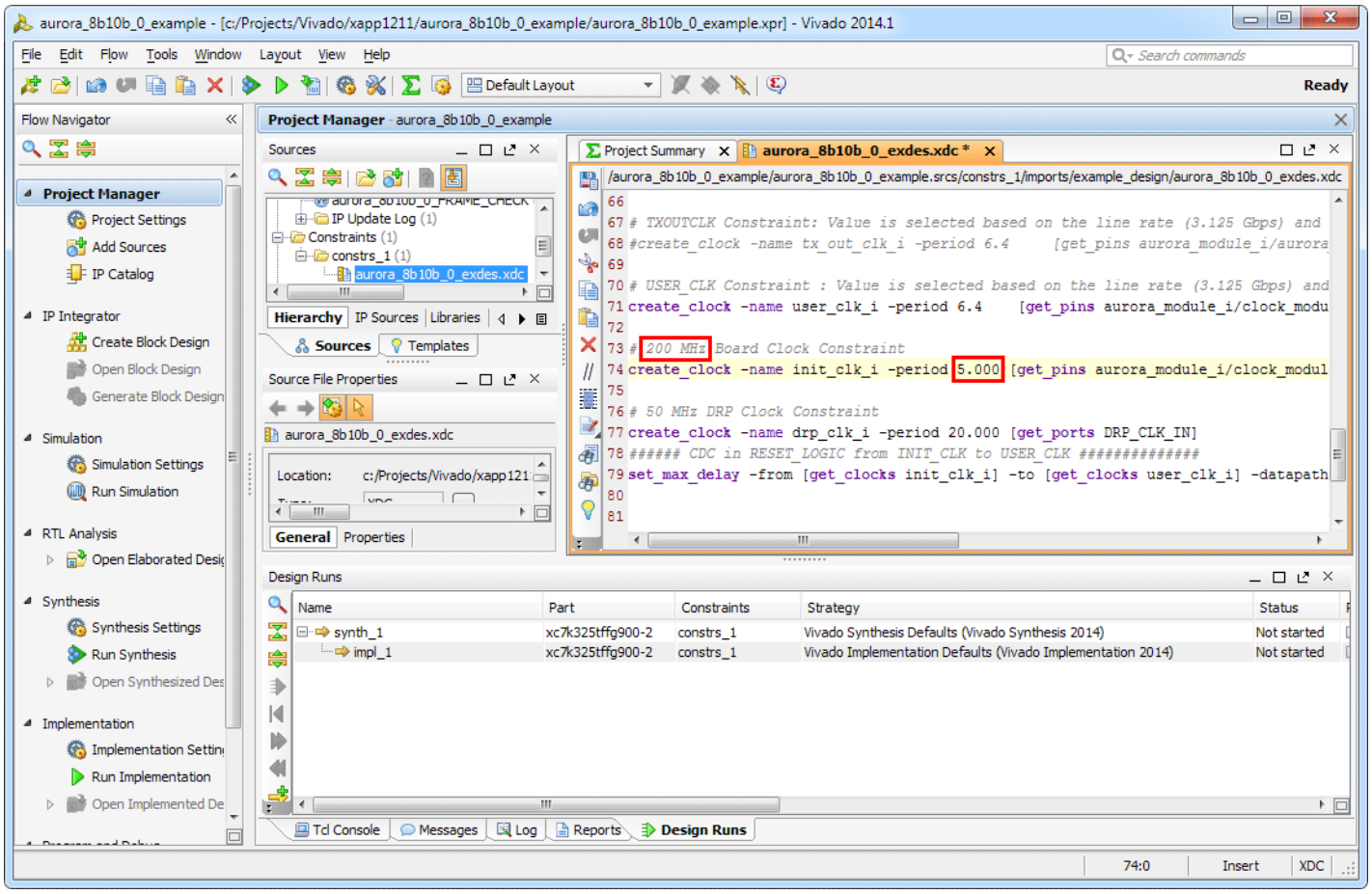

Figure 13: **Simplex Board Clock Constraint**

11. This example contains unconstrained pins. To permit bitsream file generation, add this line to the end of the constraints file (Figure 14):

    ```
    set_property BITSTREAM.General.UnconstrainedPins {Allow} [current_design]
    ```

    Caution! Spelling is critical. Double-check changes to the constraints file before proceeding.

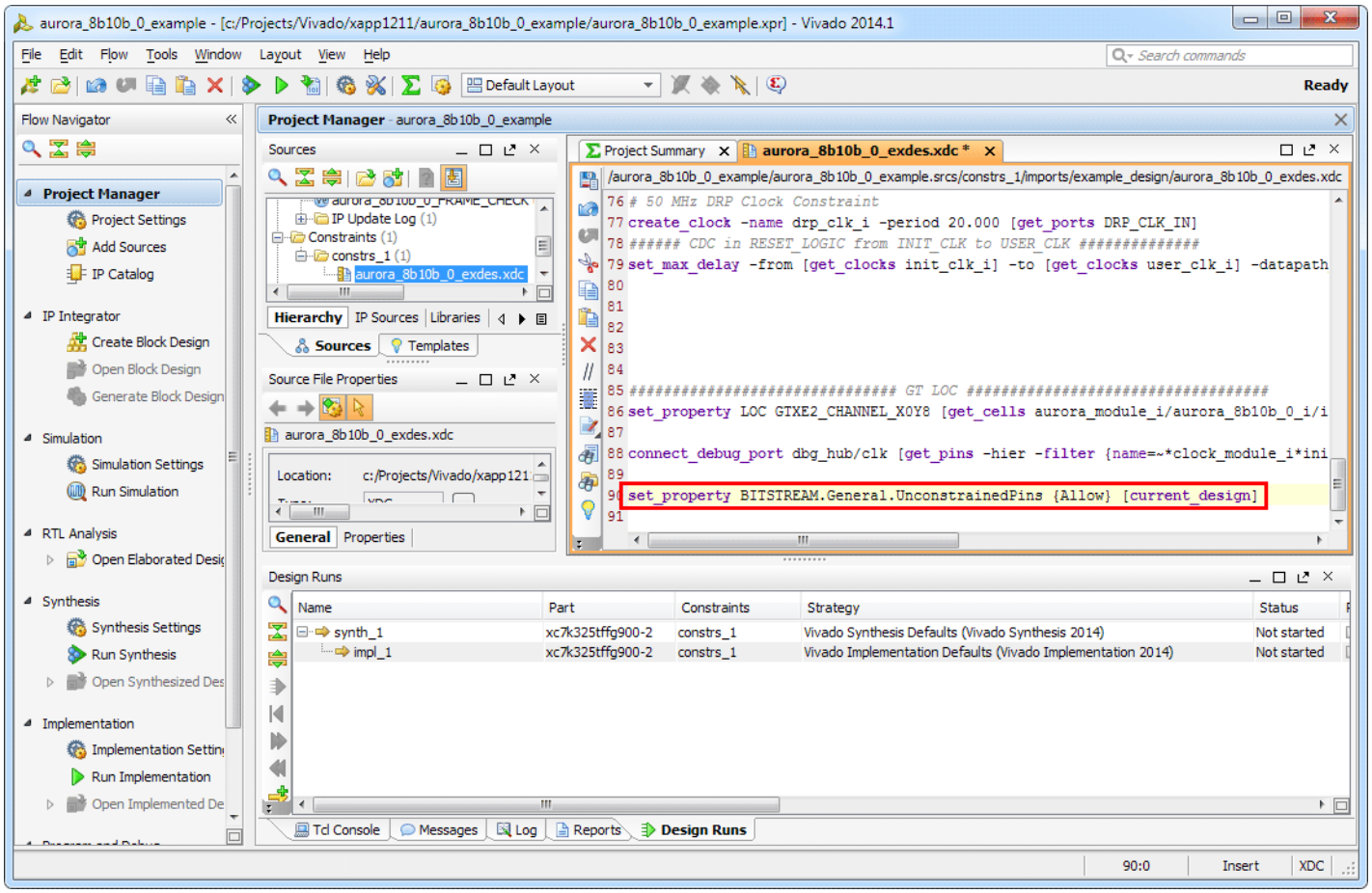

Figure 14: **Aurora 8B/10B Simplex Unconstrained Pins Property**

12. Right-click within the constraints file editor window and select **Save File**. Close the constraints file editor window.
13. Select **Generate Bitstream** from the Flow Navigator panel.
14. Click **Yes** to launch Synthesis and Implementation and proceed with bitstream file generation.
15. Repeat the steps under Customizing the Aurora Core and Synthesizing the Example Design to generate the bitstream file for the alternate platform:
    - Set **Dataflow Mode** to **TX-only Simplex** for the transmit platform
    - Set **Dataflow Mode** to **RX-only Simplex** for the receive platform

Executing the Reference Design in Hardware

Setting up the Simplex Example Design

This example illustrates a single-lane Aurora 8B/10B simplex connection between two platforms (see Figure 1, page 2). The platforms consist of two Kintex-7 FPGA KC705 Evaluation Kit boards shown in Figure 15.

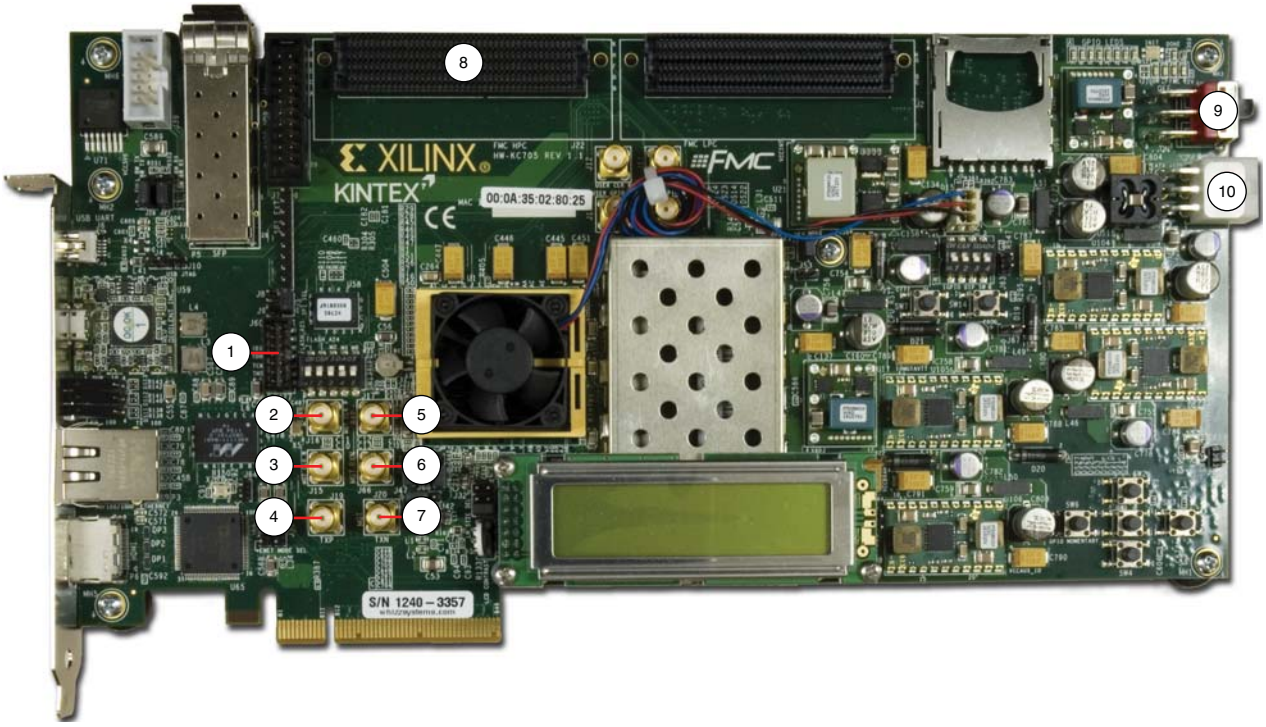

Figure 15: **KC705 Board Features**

In these instructions, numbers in parentheses correspond to callout numbers in Figure 15. Make these connections using the SMA to SMA connector cables.

- Connect TXP from board 1 (4) to RXP of board 2 (5).
- Connect TXN from board 1 (7) to RXN of board 2 (6).
- Connect CLKP from clock source 1 to MGT CLK P of board 1 (2).
- Connect CLKN from clock source 1 to MGT CLK N of board 1 (3).
- Connect CLKP from clock source 2 to MGT CLK P of board 2 (2).
- Connect CLKN from clock source 2 to MGT CLK N of board 2 (3).
- Connect a JTAG platform USB cable from the host PC to the platform cable header of board 1 (1).
- Connect a JTAG platform USB cable from the host PC to the platform cable header of board 2 (1).
- Connect a KC705 Universal 12v power adapter cable to the power connector (10) of both boards.
- If sideband mode is selected, connect a Samtec HPC-to-HPC cable between the HPC connectors (8) of both boards.
- Set the power switch (9) of both boards to the ON position.

The completed setup should resemble that shown in Figure 16. Figure 17 shows the completed setup with sideband mode.

Note: Separate clock sources should be used for each board.

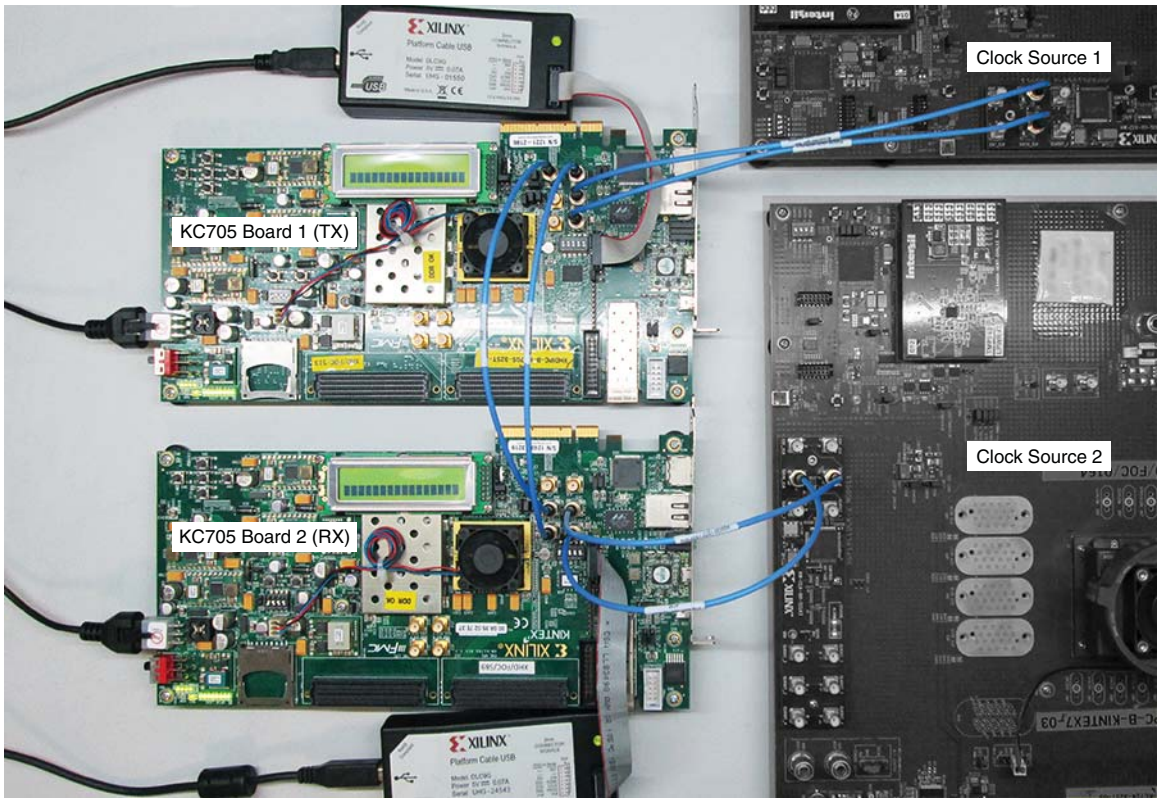

Figure 16: **Aurora 8B/10B Simplex Setup**

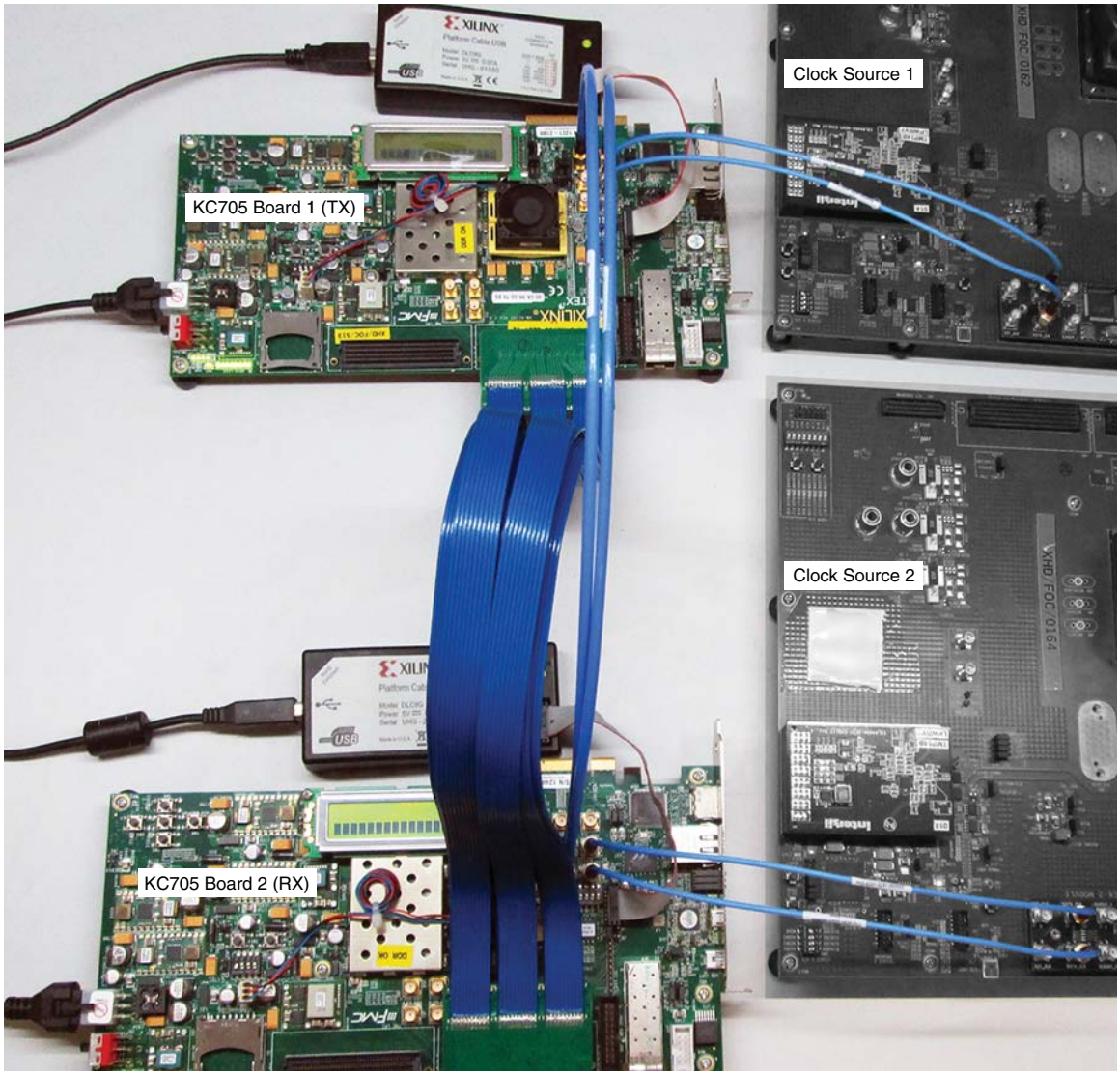

Figure 17: **Aurora 8B/10B Simplex Setup with Sideband Mode**

Setting Up the Simplex Example Hardware Session

For back channel testing in sideband mode, skip to Programming the Devices for Back Channel Testing in Sideband Mode, page 25

Programming the Devices for Back Channel with Timer Selection

1. On completion of bitstream generation, select **Flow > Open Hardware Manager** (Figure 18).

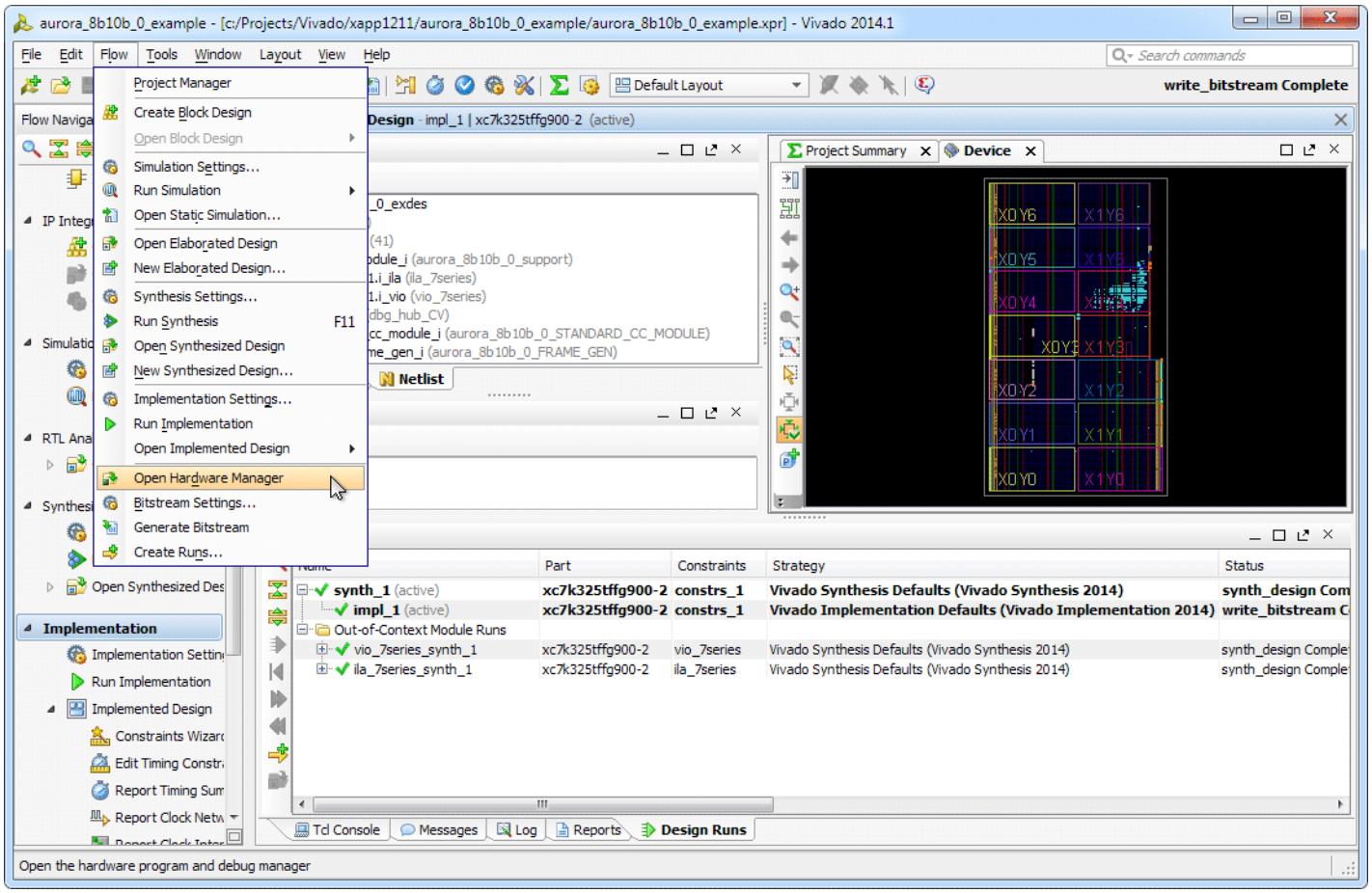

Figure 18: **Open Hardware Manager**

2. At the top of the Hardware Manager panel (see Figure 19), click **Open a new hardware target** and Click **Next**.

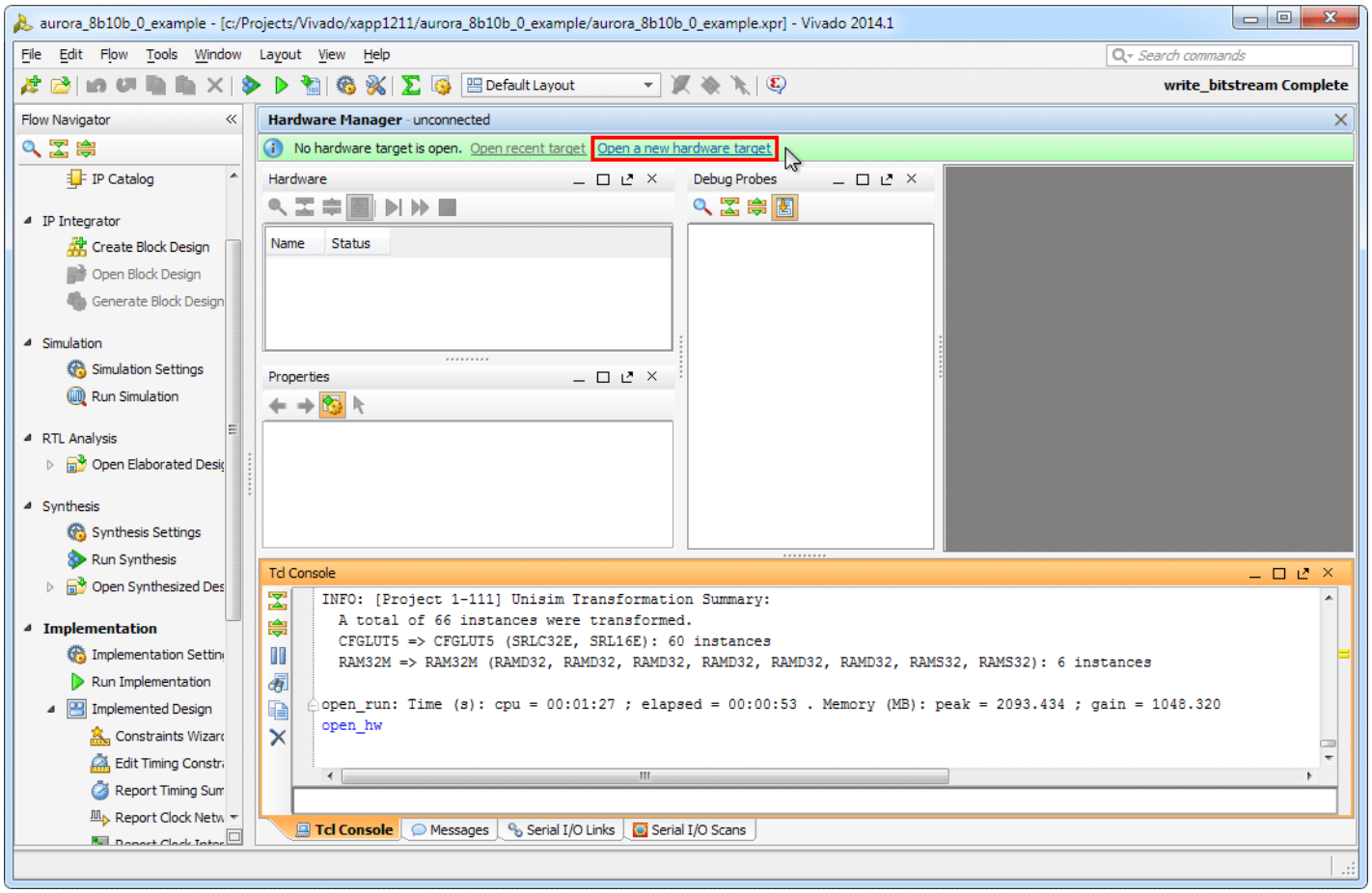

Figure 19: **Open a New Hardware Target**

3. Select **Local server** and click **Next** (Figure 20).

   Note: This operation assumes the hardware target is connected to the host PC running Vivado Design Suite. It is possible to connect the hardware target to a second, networked host PC using the Vivado CSE Server application. For details, see the *Vivado Design Suite User Guide: Programming and Debugging* (UG908), [Ref 4].

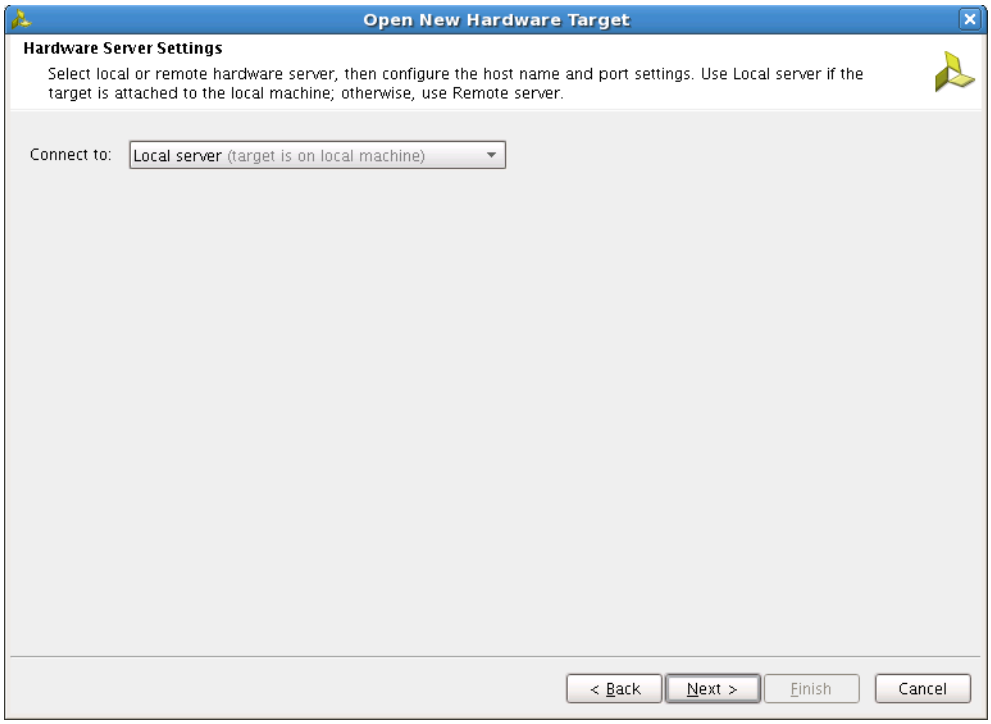

Figure 20: **Hardware Server Settings**

4. On the Select Hardware Target page, set the **JTAG Clock Frequency** for both boards to **750000 Hz** (Figure 21).

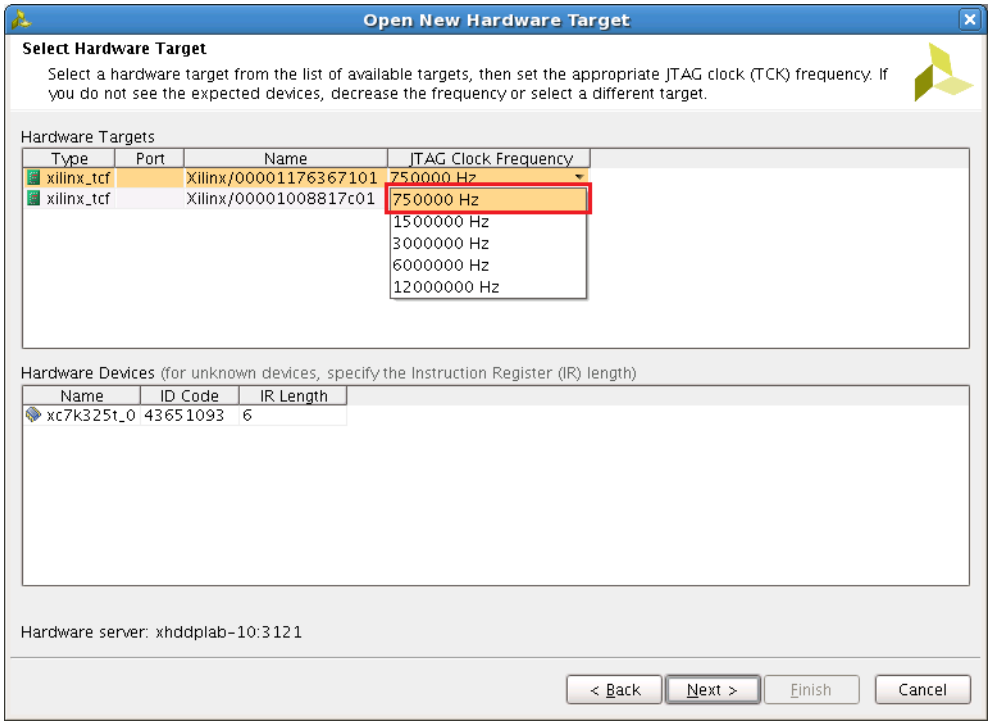

Figure 21: **Select Hardware Target**

5. Highlight the target board to be programmed and click **Next**, then **Finish**.
6. In the Hardware panel, click the active device, `XC7K325T_0(3) (Active)`.

7. In the Hardware Device Properties panel, set **Programming file** to the bitstream file name for the receive platform and set **Probes file** to the appropriate .ltx probes file name (Figure 22).

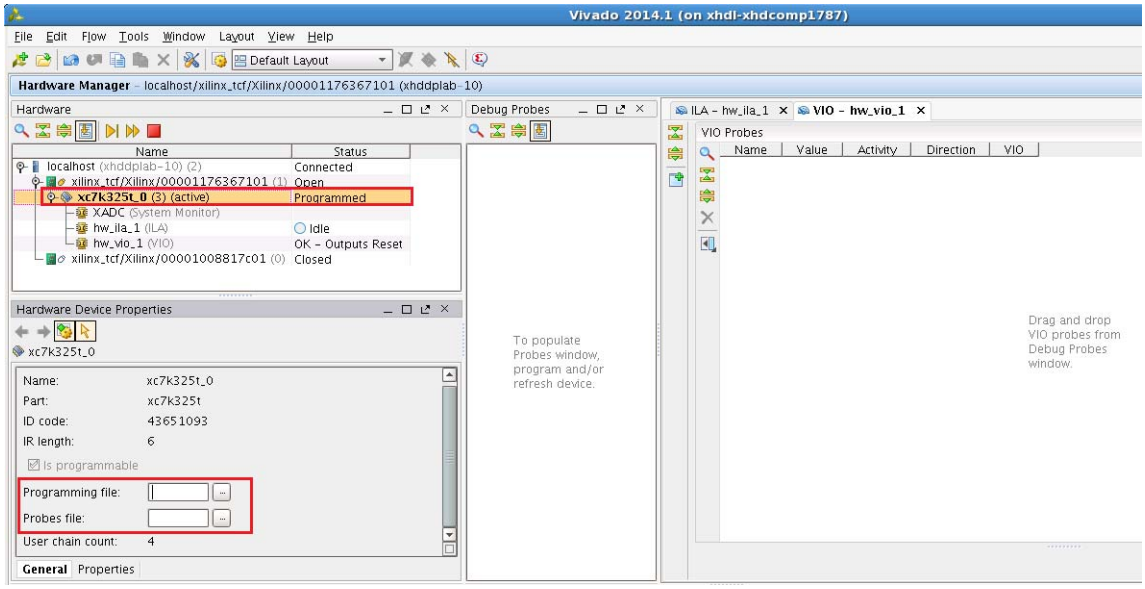

Figure 22: **Hardware Device Properties**

8. Right-click the device in the Hardware list and select **Program Device...** (Figure 23). Ensure that the bitstream file path and name are correct and click **OK**.

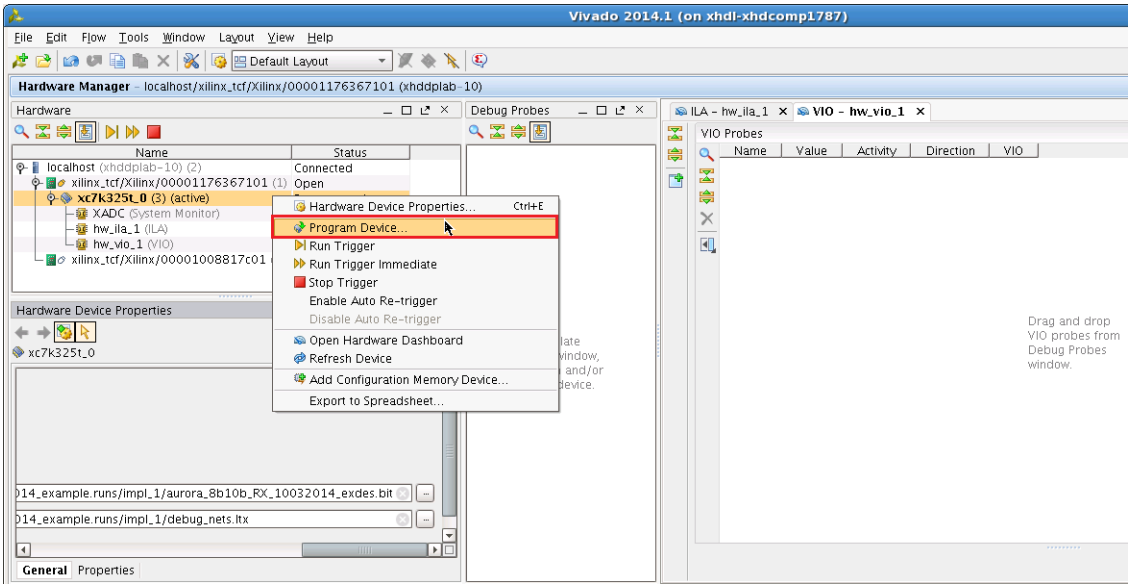

Figure 23: **Program Device**

9. When programming completes, right-click the programmed target device in the Hardware list and select **Close Target** (Figure 24).

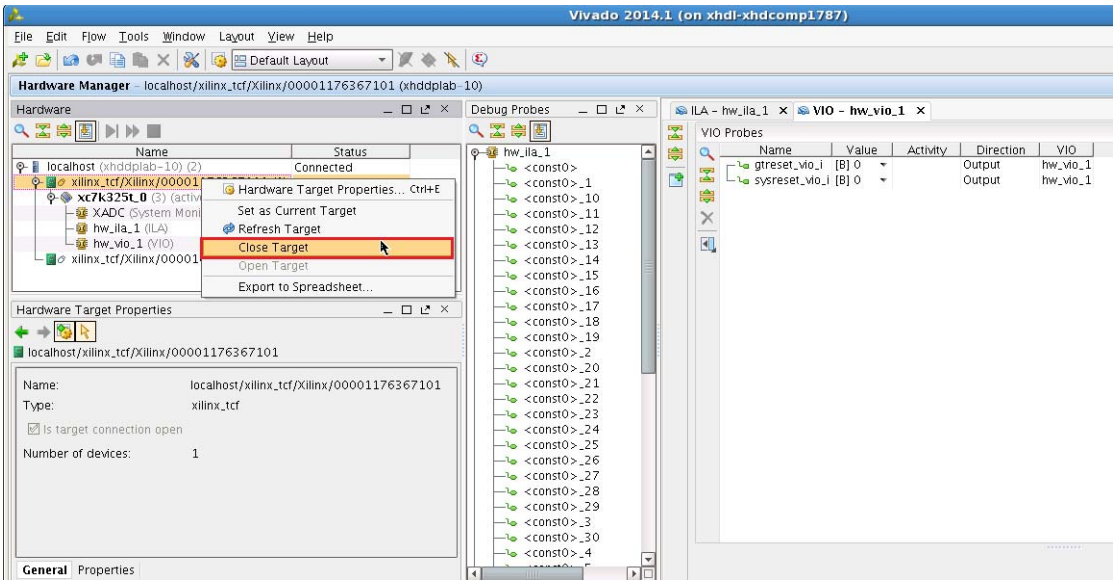

Figure 24: **Close Target**

10. Right-click the second target platform in the Hardware list and select **Open Target** (Figure 25).

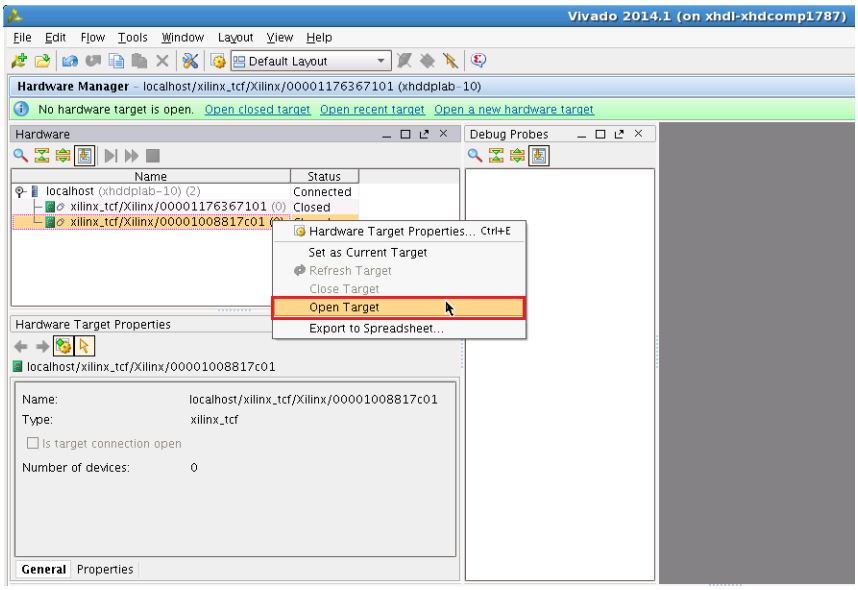

Figure 25: **Open Second Target Platform**

11. Repeat step 6 and step 7 using the bitstream file name for the transmit platform and the appropriate .ltx probes file name.
12. Repeat step 8 to program the device.
13. When programming completes, right-click the programmed target device in the Hardware list and select **Refresh Device** (Figure 26).

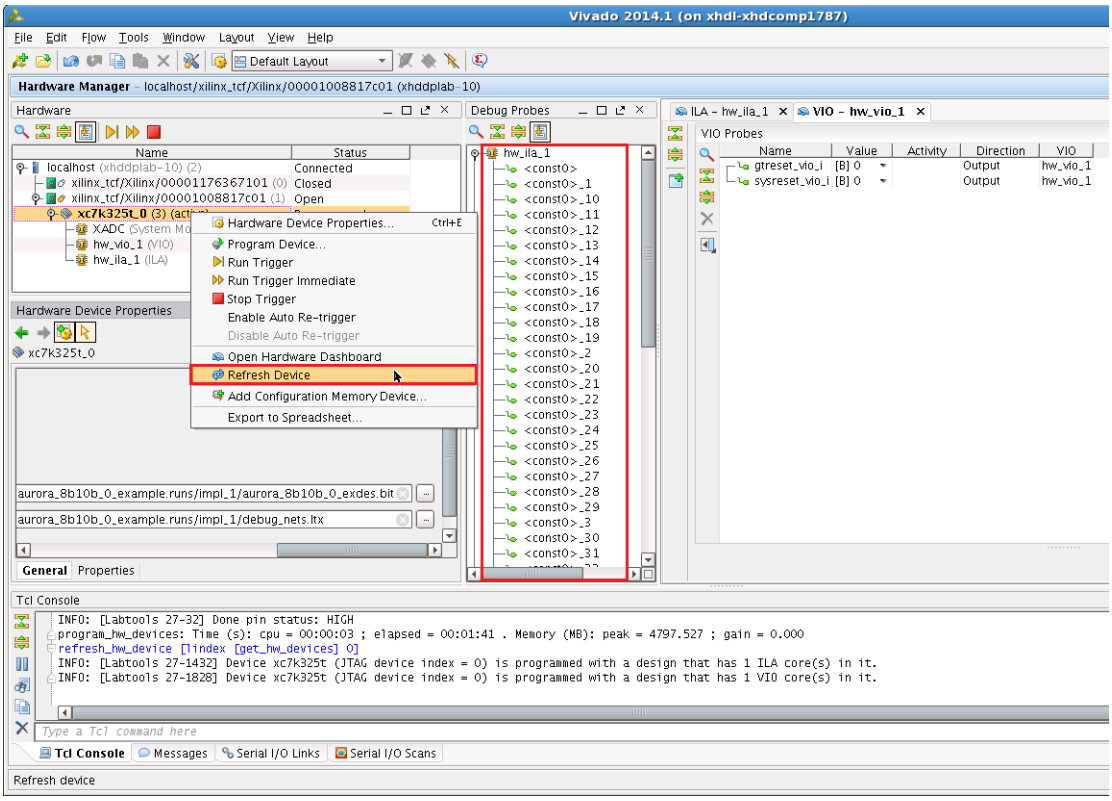

Figure 26: **Refresh Device**

14. Observe that the CHANNEL_UP and LANE_UP LEDs are lit on both platform boards (see Table 2).

Table 2: **Push Button Switches and LED Locations**

Pin Name	LOC Value	Switches/LEDs
RESET	AG5	SW6
GT_RESET_IN	AC6	SW3
LANE_UP	AB8	GPIO_LED_0
CHANNEL_UP	AA8	GPIO_LED_1

Executing the Design

1. Right-click the device in the Hardware list and select **Run Trigger** (Figure 27).

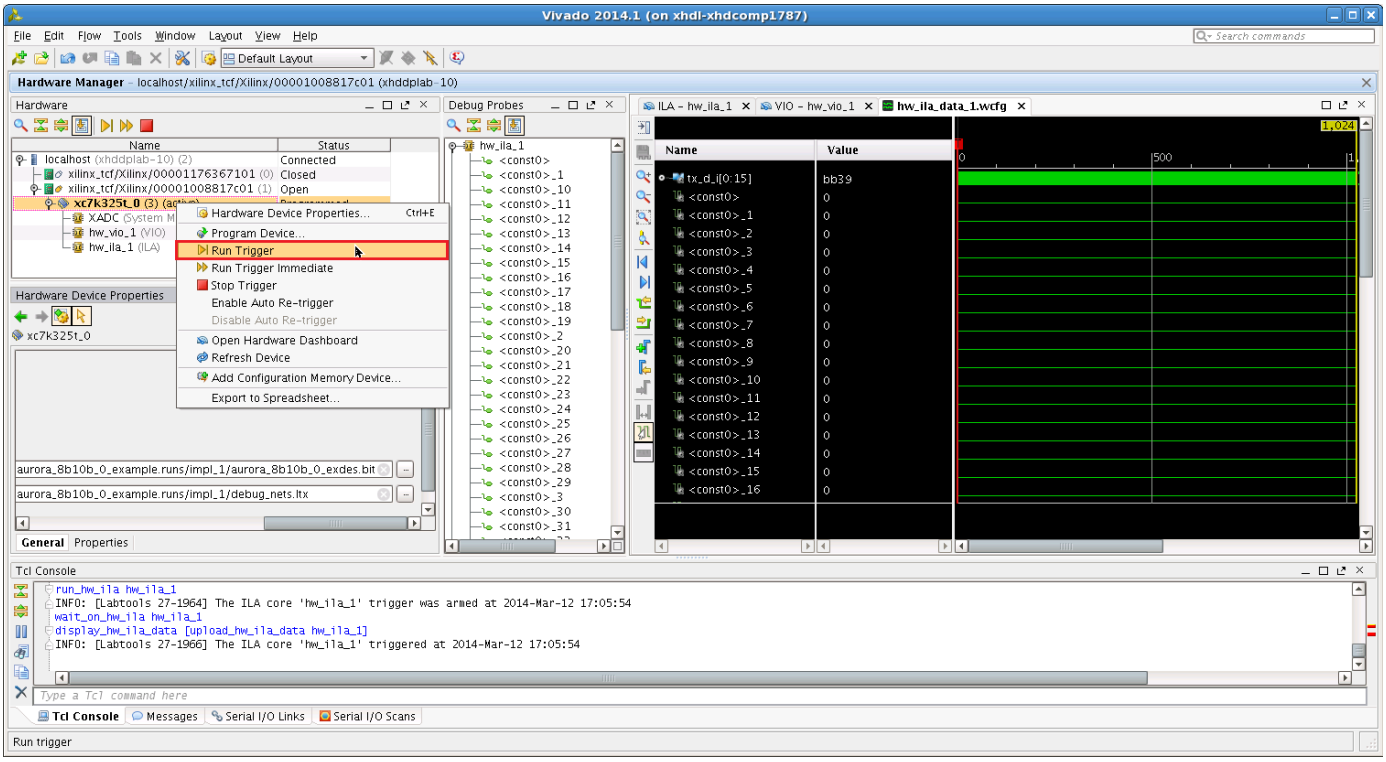

Figure 27: **Run Trigger**

2. In the waveform window that appears, observe a High state on the `lane_up` and `channel_up` signals.
3. Control-click to select these signals in the Debug Probes list under **hw_vio_1**:
   - `tx_channel_up_r`
   - `lane_up_i_i`
   - `gtreset_vio_i`
   - `sysreset_vio_i`
4. Right-click a highlighted signal and select **Add Probes to VIO Window** (Figure 28).

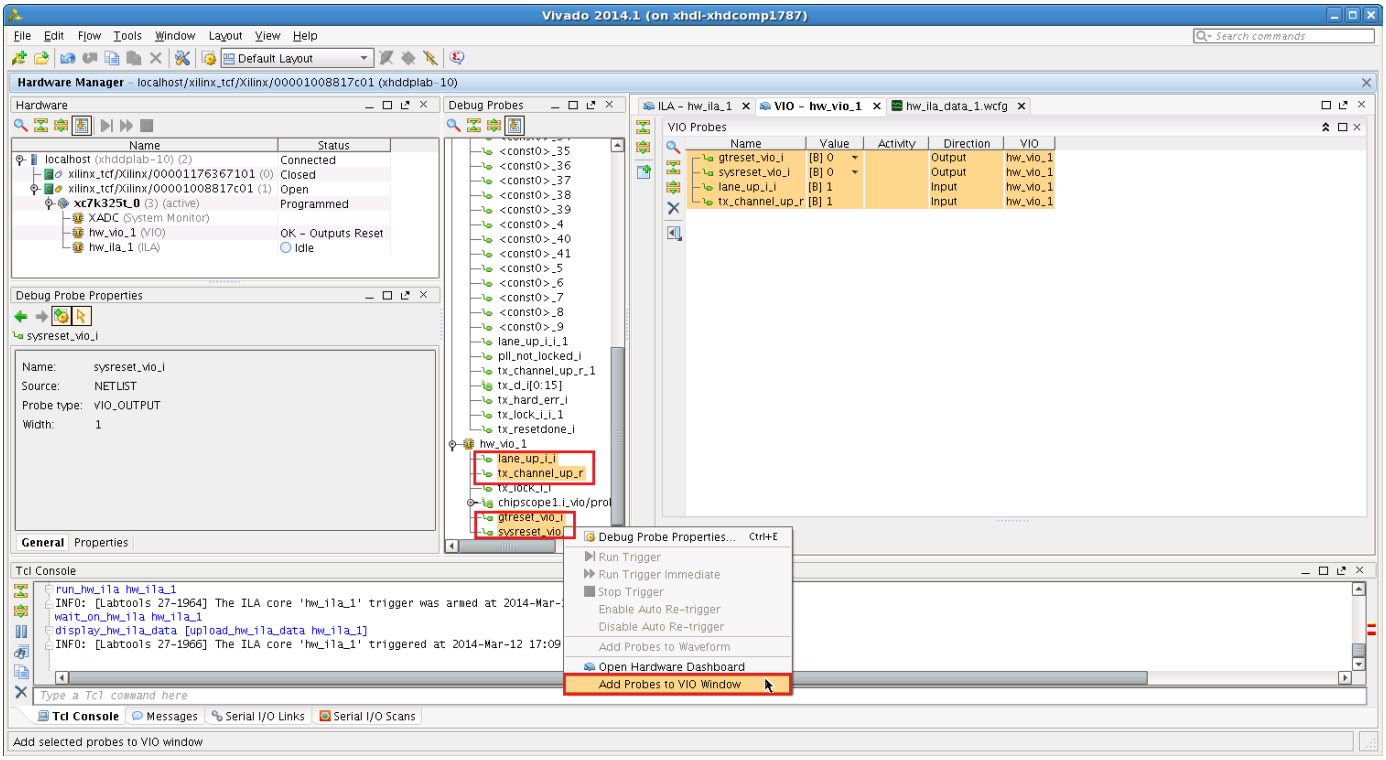

Figure 28: **Add Probes to VIO Window**

5. Toggle the reset signals by clicking the value field for each signal. Enter **1** or **0** and click **OK**.
6. The `tx_channel_up_r` and `lane_up_i_i` signals should go Low, then return High after each reset signal is toggled.

Follow these steps to view the results of the reset signals in the waveform display:

1. Set one of the reset signals High.
2. Right-click the device in the Hardware list and select Run Trigger.
3. Click the waveform display tab and observe the results of the reset signal shown in Figure 29.

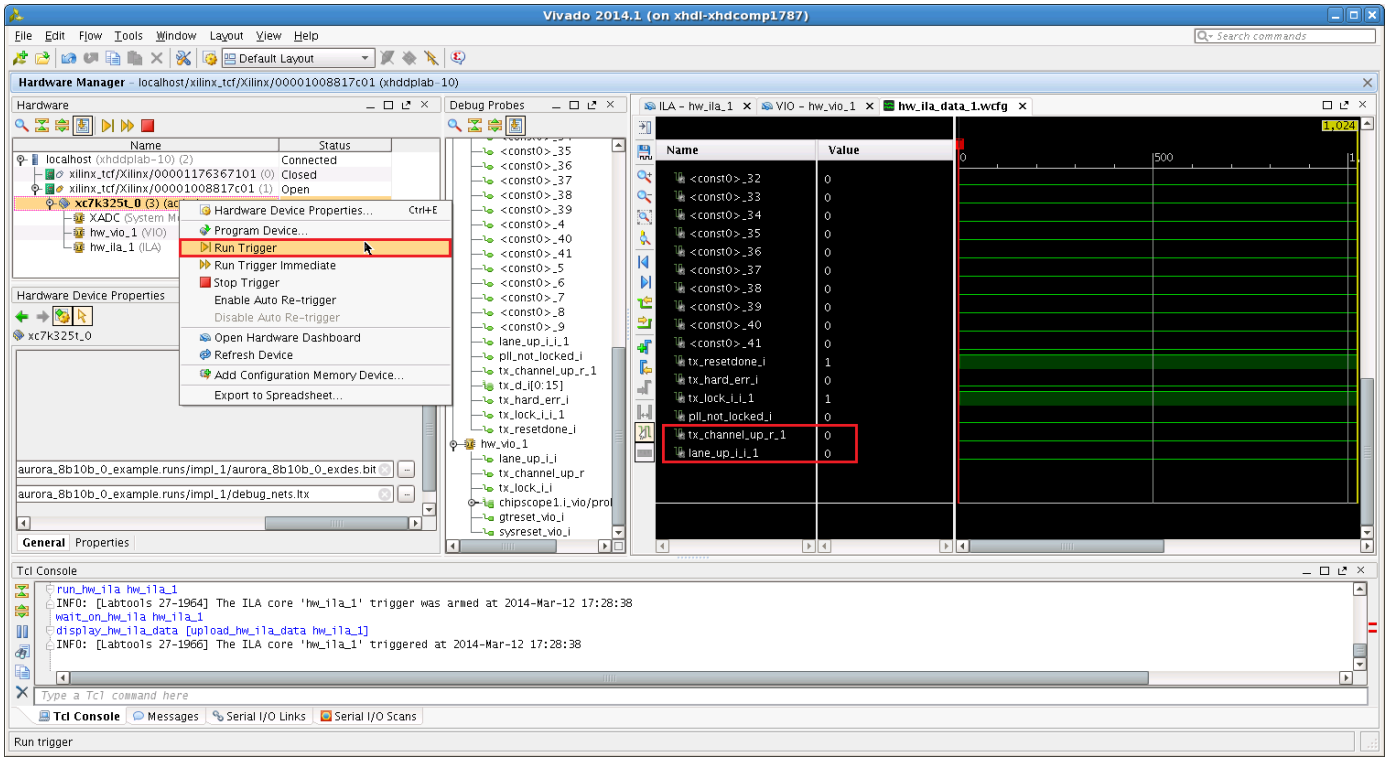

Figure 29: **Reset Signal Results in Waveform**

4. Repeat step 2 and step 3 after each change to the reset signals to observe the results.

The preceding steps attempt to demonstrate that when either `sysreset_vio_i` or `gtreset_vio_i` are asserted, both `tx_channel_up_r` and `lane_up_i_i` go Low as the core (or transceiver) is in reset state. However, when both `sysreset_vio_i` and `gtreset_vio_i` are Low, the core is out of reset state and both `tx_channel_up_r` and `lane_up_i_i` are High.

Programming the Devices for Back Channel Testing in Sideband Mode

Ensure that hardware connections are established as shown in Figure 17, page 16 before proceeding with sideband testing.

1. Disconnect the JTAG cable to the transmit platform board. Optionally, the cable can be disabled as shown in Figure 30.

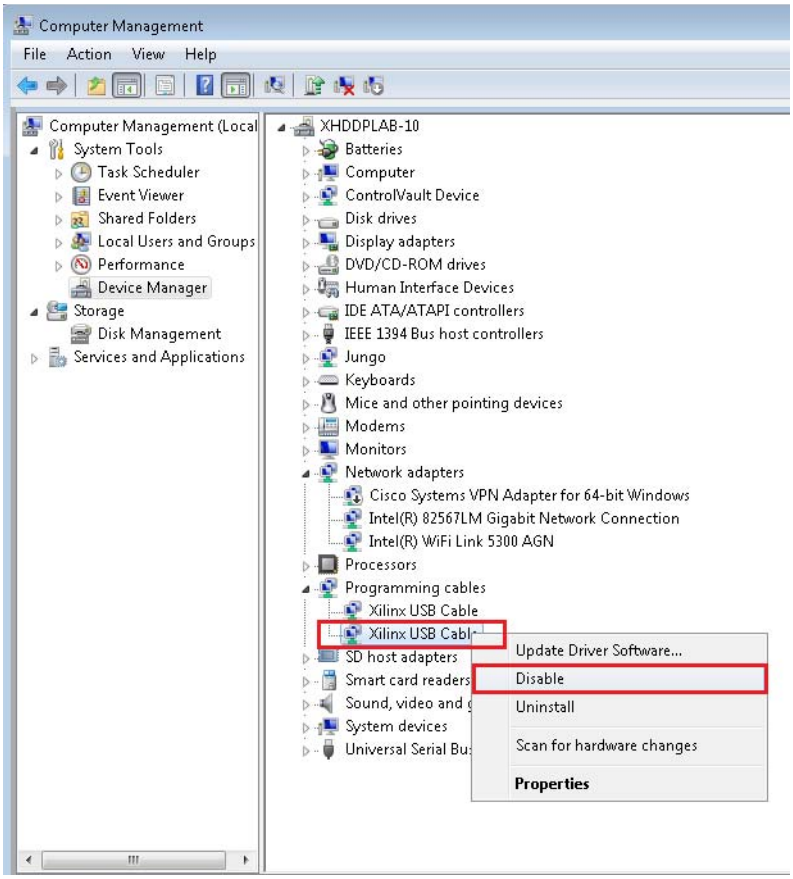

Figure 30: **Disable USB JTAG Cable**

2. In a Windows command prompt or terminal window, enter this command to change directories to the receive platform bitstream file location:

```
% cd <Rx project directory>/aurora_8b10b_0_example/
  aurora_8b10b_0_example.runs/impl_1
```

3. Enter these commands to invoke the Xilinx Microprocessor Debugger tool (XMD) and download the bitstream file:

```
% xmd
XMD% fpga -f aurora_8b10b_0_exdes.bit
XMD% exit
```

4. Disconnect the JTAG cable from the receive platform board and connect the cable to the transmit platform board. Optionally, enable the transmit platform cable and disable the receive platform cable as shown in Figure 30.

5. In a Windows command prompt or terminal window, enter this command to change directories to the receive platform bitstream file location:

```
% cd <Tx project directory>/aurora_8b10b_0_example/
  aurora_8b10b_0_example.runs/impl_1
```

6. Enter these commands to invoke XMD and download the bitstream file:

```
% xmd
XMD% fpga -f aurora_8b10b_0_exdes.bit
XMD% exit
```

7. Observe that the CHANNEL_UP and LANE_UP LEDs are lit on both platform boards (see Table 2, page 22).

Back Channel Testing in Sideband Mode

Refer to Table 2, page 22 for location of buttons and LEDs used in these steps.

1. Press RESET (SW6) on the receive platform board and observe that the CHANNEL_UP and LANE_UP LEDs on both boards are not lit. After releasing RESET, the CHANNEL_UP and LANE_UP LEDs on both boards should be lit. Similar behavior should be observed when pressing and releasing GT_RESET_IN (SW3).
2. Press RESET (SW6) on the transmit platform board and observe that the LANE_UP LED remains lit while the CHANNEL_UP LED is not lit. After releasing RESET, the CHANNEL_UP and LANE_UP LEDs should be lit. Similar behavior should be observed when pressing and releasing GT_RESET_IN (SW3).

Reference Design

Table 3 shows the reference design checklist.

Table 3: **Reference Design Checklist**

Parameter	Description
General	
Target devices (stepping level, ES, production, speed grades)	Kintex-7 XC7K325T-2FFG900
Source code provided	Yes
Source code format	Verilog (VHDL indirect support through vho/netlist)
Design uses code/IP from existing Xilinx application note/reference designs, Vivado IP Catalog, or third party	Reference design provided by Aurora core generated from Vivado IP catalog
Simulation	
Functional simulation performed	No
Timing simulation performed	No
Test bench used for functional and timing simulations	N/A
Test bench format	N/A
Simulator software/version used	N/A
SPICE/IBIS simulations	No
Implementation	
Synthesis software tools/version used	Vivado Design Suite 2014.1
Implementation software tools/versions used	Vivado Design Suite 2014.1
Static timing analysis performed	Yes
Hardware Verification	
Hardware verified	Yes
Hardware platform used for verification	Kintex-7 FPGA KC705 evaluation kit

Conclusion

The Kintex-7 FPGA KC705 Evaluation Kit provides an excellent platform to implement and test the LogiCORE IP Aurora 8B/10B core. Following the procedure outlined in this application note, Aurora 8B/10B simplex designs can be verified and extended for specific applications. Various configurations can be quickly evaluated using only the KC705 board, a clock source and the Vivado Design Suite.

References

This application note uses these references:

1. *LogiCORE IP Aurora 8B/10B Product Guide* (PG046)
2. *Kintex-7 FPGA KC705 Evaluation Kit Getting Started Guide* (UG883)
3. *Vivado Design Suite User Guide: Designing with IP* (UG896)
4. *Vivado Design Suite User Guide: Programming and Debugging* (UG908)
5. *Embedded System Tools Reference Manual* (UG111)

Revision History

The following table shows the revision history for this document.

Date	Version	Description of Revisions
01/09/2015	1.0	Initial Xilinx release.

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