ACTEL CORPORATION

ACTEL TRAINING

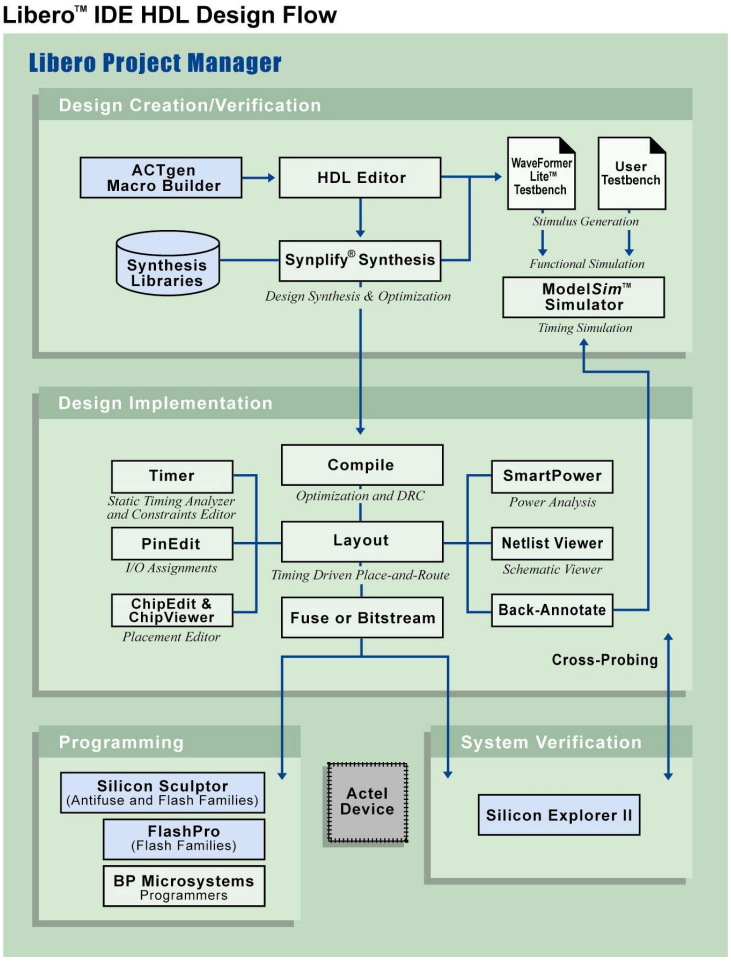
VHDL LAB GUIDE FOR LIBERO IDE ver2.3

Section i

Introduction to the Actel VHDL Design Flow

Introduction

This guide will take you through the design flow for VHDL using Actel Libero IDE version 2.3. It explains briefly how to use the software tools and provides information about the example design.



Actel VHDL Design Flow

Overview

Purpose

The purpose of this lab is to become familiar with the Actel VHDL design flow. For this exercise, we will implement a 16-bit loadable counter with an asynchronous reset and synchronous enable in an AX500 FPGA.

Tools

For this lab, you will use the following tools:

- Libero IDE ver 2.3
- WaveFormer Lite 8.9
- ModelSim for Actel ver 5.6b
- Synplicity ver 7.2
- Designer R1-2003

Function

16 bit synchronous counter triggered with the positive edge of the clock

Pin list

ENABLE = enable count active high

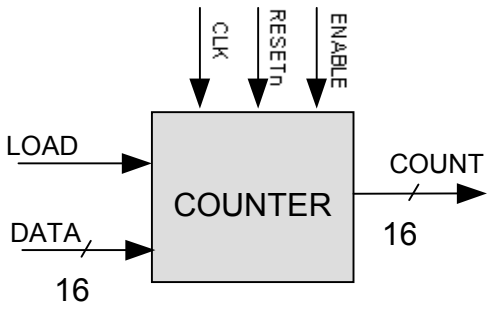
RESETn = asynchronous reset of the counter active low

CLK = master clock

LOAD = parallel load of the counter active high

DATA = 16 bit data input to counter

COUNT = 16 bit counter output



Counter block diagram

Section 1

Creating a project in Libero IDE

Creating a Libero IDE Project and entering the source file

Start Libero IDE by double clicking on the Actel Libero IDE shortcut on your desktop or by clicking **Start > Programs > Libero IDE 2.3 > Libero IDE Design Environment**.

From the File menu click *New Project*. The New Project dialog box appears, as shown.

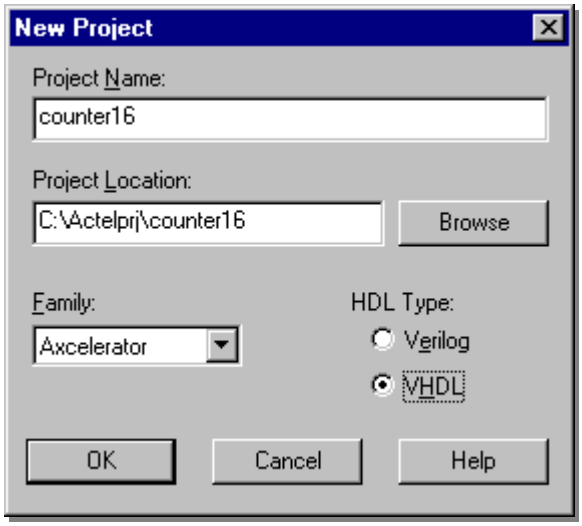
Enter the following in the New Project dialog box:

Project Name: Enter counter16 in the Project Name field (note that a folder named counter16 will be created under the specified project location)

Location: Browse to C:\Actelprj

Family: Select Axcelerator from the Family drop-down list box

HDL: Select VHDL



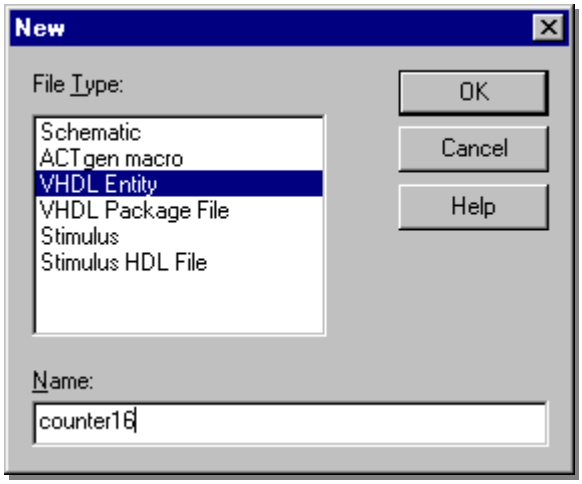
Click ***OK.*** The project "counter16" is created and opened in Libero IDE.

Creating the VHDL source file

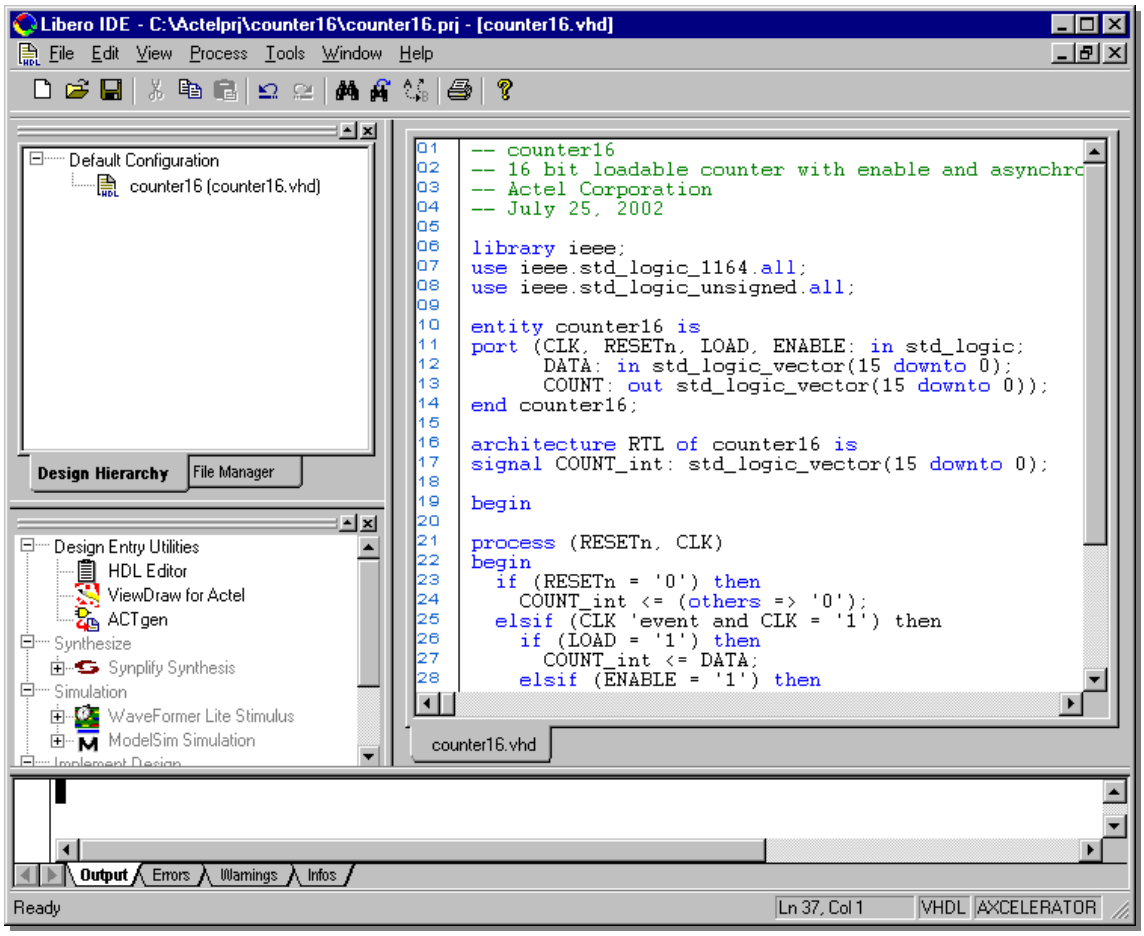
From the file menu, click **New**. In the New dialog box, select VHDL Entity and enter *counter16* as the name. Click **OK** to open the HDL editor.

In the HDL editor, enter the description of a 16 bit counter as described in the overview section.

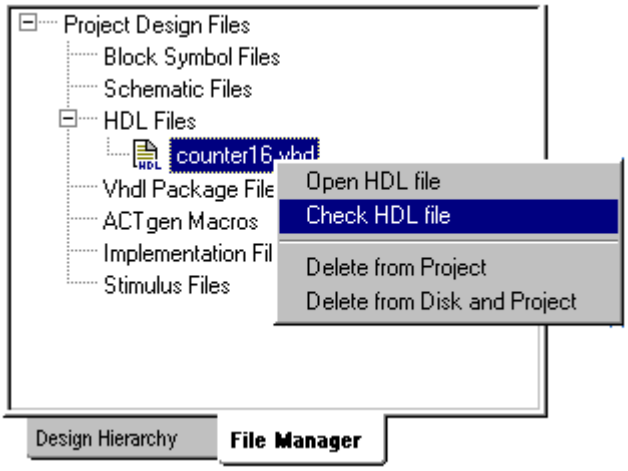
Note: you can copy the description of the counter from Appendix A of this document and paste it into the Libero IDE HDL editor.



Save the counter description by selecting **Save** from the Libero IDE **File** menu. The counter description will be visible in the HDL editor and on the Design Hierarchy tab as shown in the figure below:



Select the File Manager tab in the Libero IDE Design Explorer window. Select *counter16* under HDL Files, then right mouse click and select **Check HDL file**. If your counter description has no syntax errors,



"Syntax checking for
C:\Actelprj\counter16\hdl\counter16.vhd is successful"
will appear on the **Output** tab in the Libero IDE GUI.

Correct any syntax errors that exist in your counter description and save the file.

Section 2

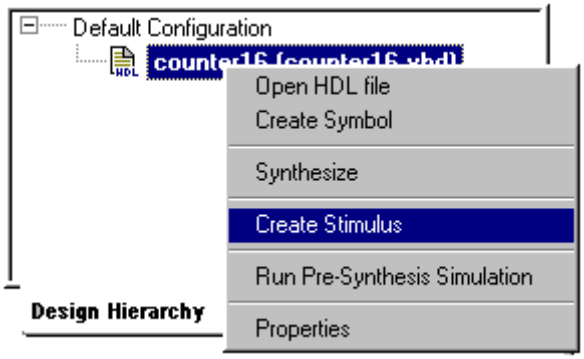
Performing functional simulation

In this section you will generate stimulus for the counter and perform a functional (pre-synthesis simulation).

Creating Stimulus with WaveFormer Lite

WaveFormer Lite generates VHDL testbenches from drawn waveforms. There are three basic steps for creating test benches using WaveFormer Lite and Actel Libero IDE:

- Import Signal Information
- Draw WaveForms
- Export the VHDL Testbench



To launch WaveFormer Lite and import signal information into it, go to the **Design Hierarchy** tab in the Libero IDE Design Explorer Window and highlight *counter16.* Right click and select **"Create Stimulus"** to invoke WaveFormer Lite.

Note: if counter16 does not appear in bold font on the Design Hierarchy tab, highlight counter16, right mouse click and select "**Set As Root"**.

WaveFormer Lite launches, with the port signals appearing in the Diagram window.

For additional information on using WaveFormer Lite, refer to the WaveFormer Lite User's Guide (wflite.pdf) which is contained in the docs folder in your Libero IDE installation path.

Generating Stimulus for the Counter

In this step, you will generate stimulus and a testbench for the *counter16* design using WaveFormer Lite.

Create the clock signal by clicking the *CLK* signal in the diagram window then right mouse clicking and selecting "**Signal(s) <-> Clock(s)**".

A Clock waveform will appear in the diagram window. Double click on the clock signal name in the diagram window to open the Signal Properties window. Click the Clock Properties button to open the "Edit Clock Parameters" window. Specify the clock parameters to generate clock signals.

Using the instructions above, create a clock signal with the following properties:

- CLK - 100 MHz
- Starting Offset: 0 (default)
- Duty Cycle: 50% (default)
- Invert (starts low) unchecked

Accept defaults for all other clock parameters. Click **OK** to close the Clock Properties dialog box.

Click **Apply** then **OK** in the Signal Properties dialog box to create the clock waveform.

Draw waveforms for the other signals as listed below:

- RESETn - low 0 ns - 35 ns

  high 35 ns - 1.2 us

- Load - low 0 ns - 775 ns

  high 775 ns - 805 ns

  low 775 ns - 1.2 us

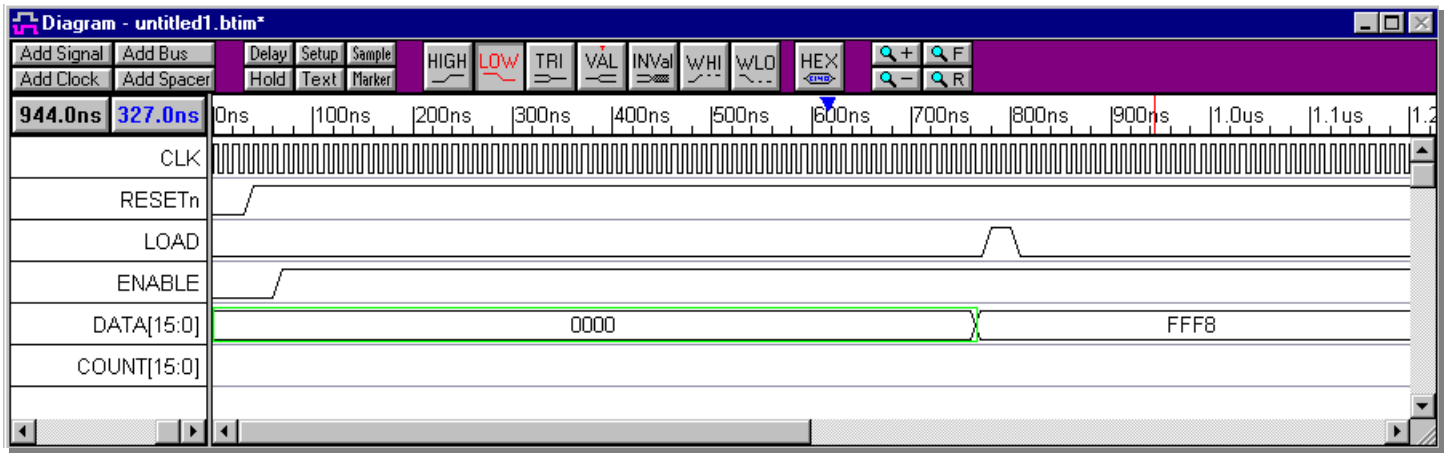
- Enable - low 0 ns - 65 ns

  high 65 ns - 1.2 us

- Data - 0000 0 ns - 765 ns

  FFF8 765 ns - 1.2 us

Your waveforms should appear as shown in the figure on the next page.

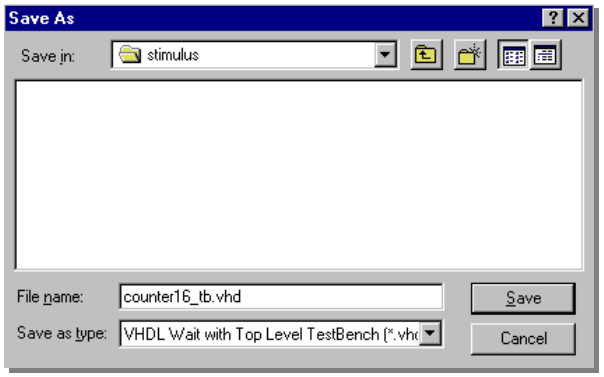


WaveFormer Lite Diagram Window

Save the timing diagram by clicking **Save** from the WaveFormer Lite **File** menu.

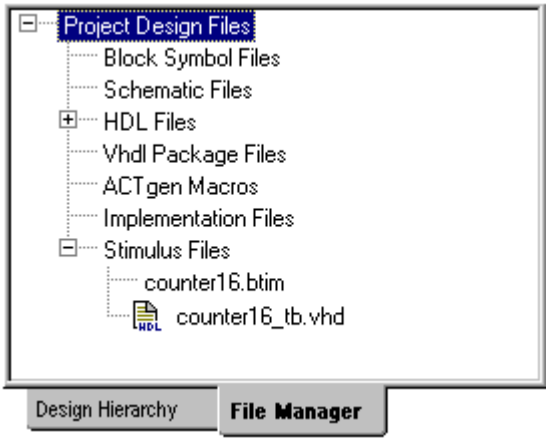
In the Save As dialog box, enter *counter16.btim* as the file name then click **Save** to save the timing diagram.

Generate the VHDL testbench by selecting **Export Timing Diagrams As** (Export menu). In the Save As dialog box, select **VHDL Wait with Top Level TestBench (*.vhd)** in the "Save As Type" pull-down menu. Enter *counter16_tb.vhd* in the filename box and click **Save** to generate the testbench. After WaveFormer Lite creates the file, it will display its contents in the Report window so that you can quickly verify that the file is correct.



Exit WaveFormer Lite by selecting **Exit** (File menu). Select **Yes** when prompted about closing all text files.

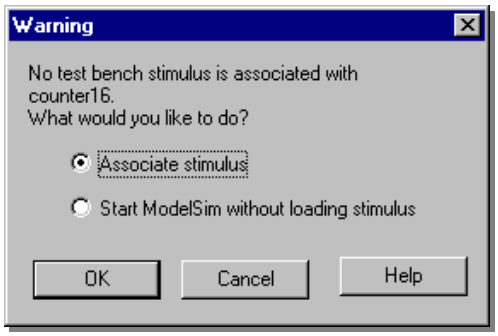
The waveform file and the testbench will appear on the File Manager tab in the Libero IDE Design Explorer window.



Performing pre-synthesis simulation with ModelSim for Actel

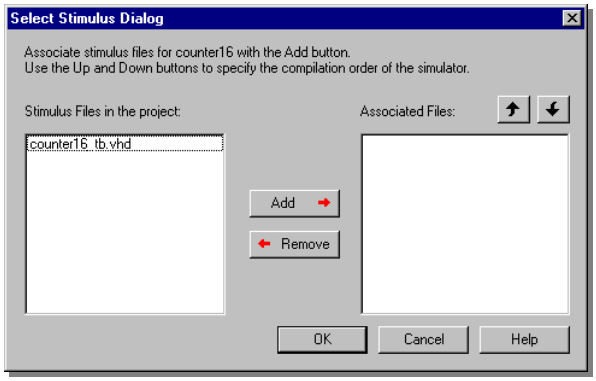
To perform pre-synthesis simulation, double click the **ModelSim Simulation** button in the Libero IDE Process window, or right mouse click on *counter16* (*Design Hierarchy* tab) in the Design Explorer Window and select **Run Pre-Synthesis Simulation**.

A dialog box will open indicating that no testbench stimulus is associated with counter16. Select the **Associate stimulus** radio button and click **OK**.

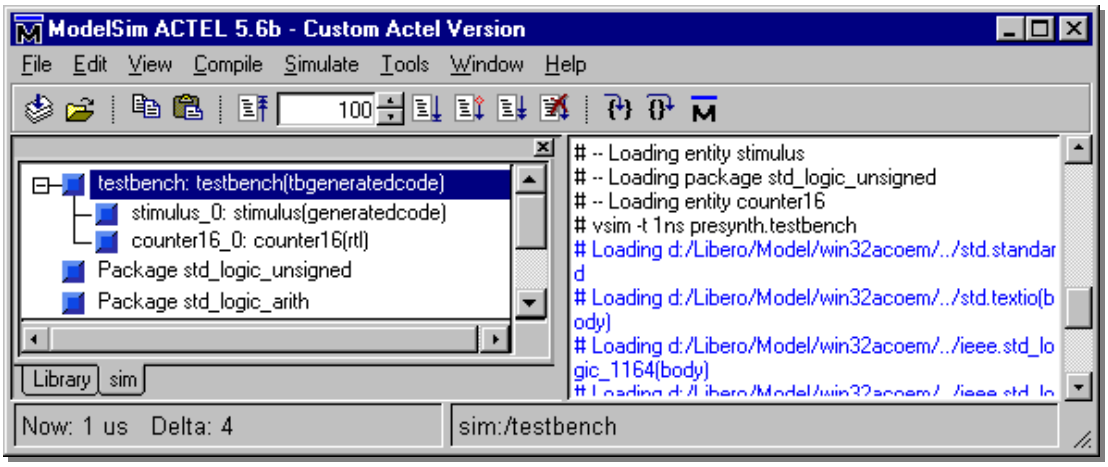


In the Select Stimulus dialog box, highlight counter16_tb.vhd and click **Add** to add the testbench to the Associated Files box.

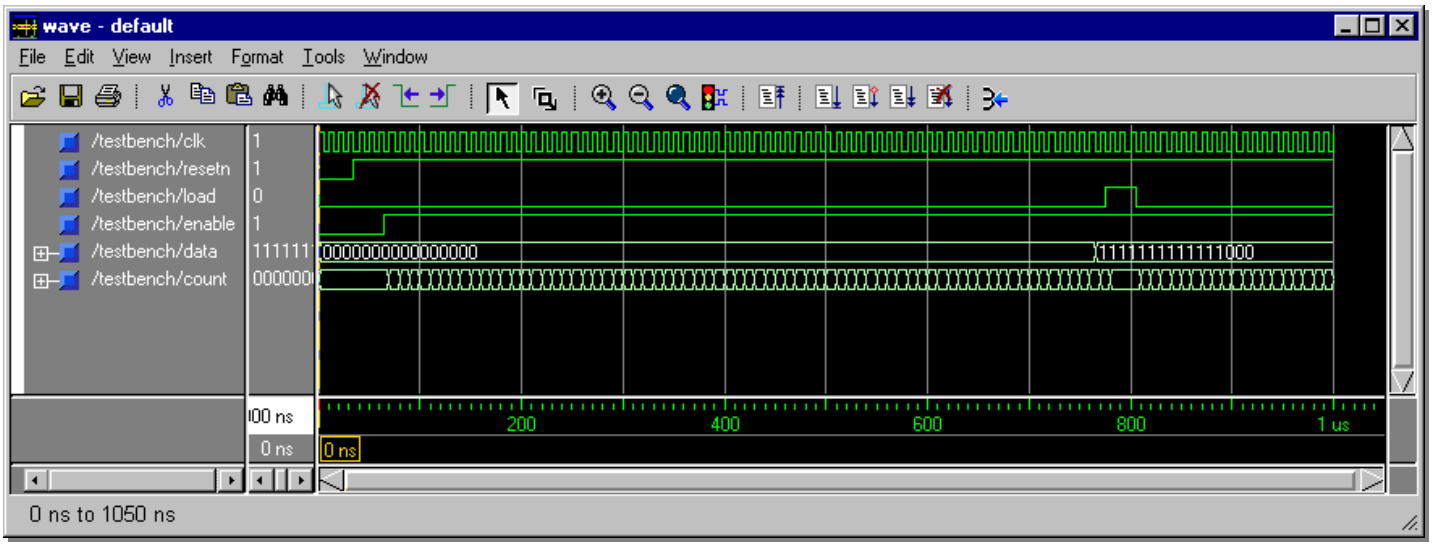
Click **OK** to close the Select Stimulus dialog box and launch the ModelSim for Actel simulator.



The ModelSim for Actel VHDL Simulator will open and compile the source file and the testbench.

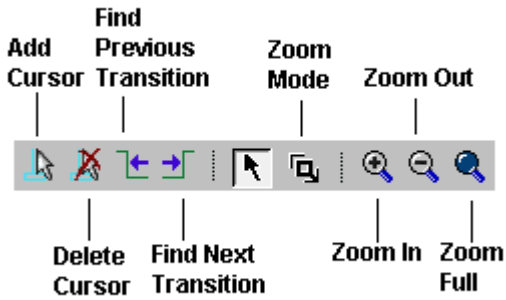


When the compilation completes, the simulator will run for 1 us and a Wave window will open to display the simulation results.



ModelSim for Actel Wave Window

Scroll in the wave window to verify the counter works correctly. Use the zoom buttons to zoom in and out as necessary. The radix for the data and count signals can be changed to improve readability.



Wave window Toolbar Buttons.

Exit the simulator by selecting **Quit** from the **File** menu in the ModelSim for ACTEL 5.6b window. Enter **Yes** in the **Quit VSIM** dialog box.

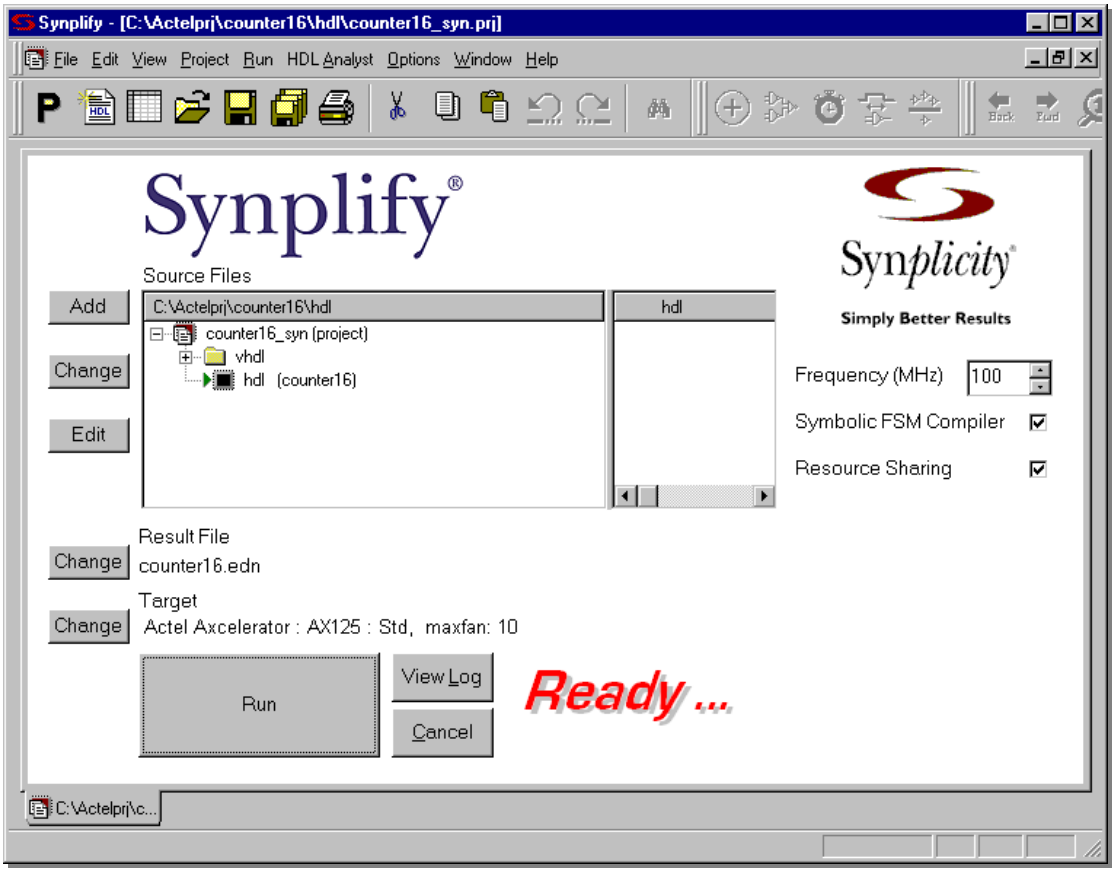
Section 3

Synthesizing the counter

Creating a Synplicity project

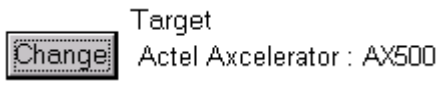
In this section, you will synthesize the counter design with Synplicity to create an EDIF netlist.

Invoke Synplify by double clicking the **Synplify Synthesis** button in the Libero IDE Process Window or by right mouse clicking on *counter16* in the Libero IDE Design Explorer Window and selecting **Synthesize**. The Synplicity main window will open.



Synplicity main window

Change the target device by clicking the **Change** button.

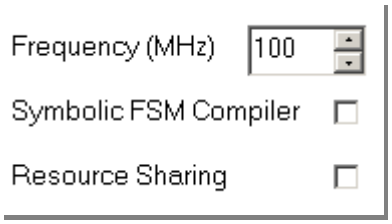


The "Options for Implementation: counter16_syn: hdl" dialog box will open. In the device tab, confirm the following are set and click **OK**:

- Technology: Actel Axcelerator
- Part: AX500
- Speed Grade: -3
- Fanout Guide: 10 (default)
- Hard Limit to Fanout: off (unchecked)
- Disable I/O Insertion: off (default).

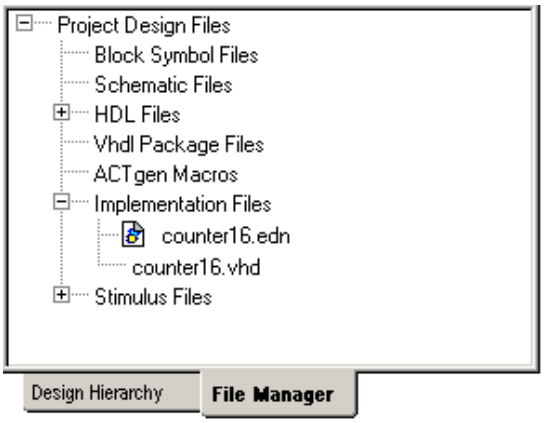
In Synplicity's main window:

- Set the Frequency to 100 MHz
- Turn resource sharing off (unchecked)
- Symbolic FSM Compiler turned off (unchecked)



Click the **RUN** button. Synplify will now compile and synthesize the *counter16* design into a file called *counter16.edn*. When the **Ready…** on the main user interface in Synplify changes to **Done…** the design has been successfully mapped to the Axcelerator family.

The resultant EDIF file, *counter16.edn*, and a structural VHDL netlist will be visible under Implementation Files on the Libero IDE File Manager tab in the Design Explorer Window.



Click on the **View Log** button and scroll through the log file to answer the following questions:

Utilization

Combinational Cells: _____ Sequential Cells: _____

Frequency

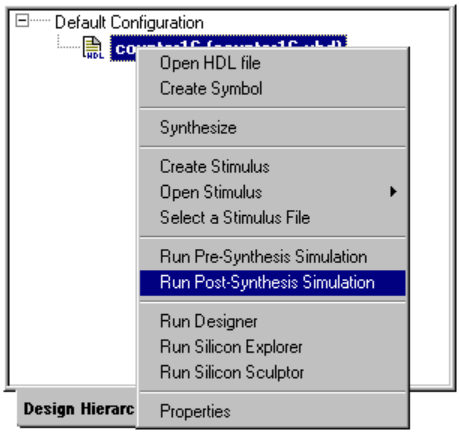
Estimate Frequency:_____ MHz _____ ns

Section 4

Simulating the counter structural VHDL netlist

In this section, you will simulate the structural VHDL netlist of the counter using the VHDL testbench that was created in section 2.

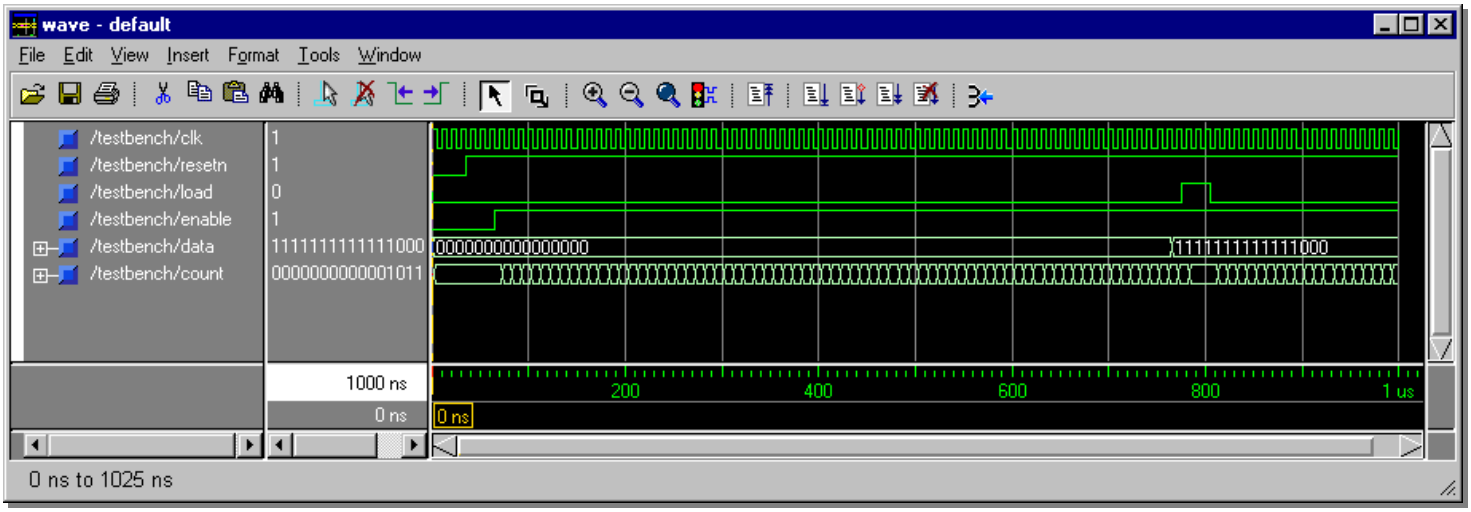
Click the **ModelSim Simulation** button in the Libero IDE Process window, or right mouse click on *counter* (*Design Hierarchy* tab) in the Design Explorer Window and select **Run Post-Synthesis Simulation**.



The ModelSim for Actel VHDL Simulator will open and compile the source file and the testbench.

When the compilation completes, the simulator will run for 1 us and a Wave window will open to display the simulation results.

Scroll in the wave window to verify the counter works correctly. Use the zoom buttons to zoom in and out as necessary. The radix for the data and count signals can be changed to improve readability.



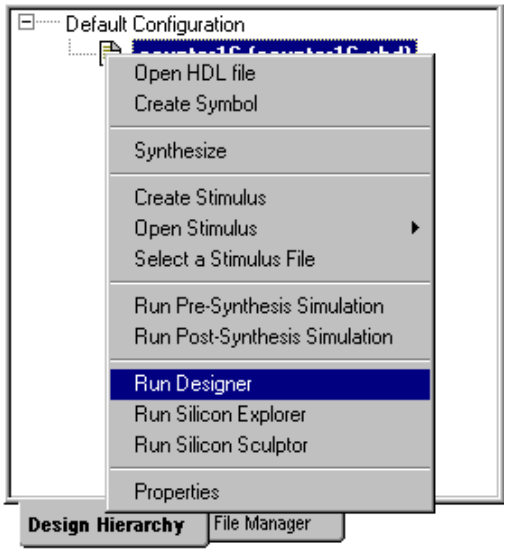
Section 5

Place and Routing the COUNTER

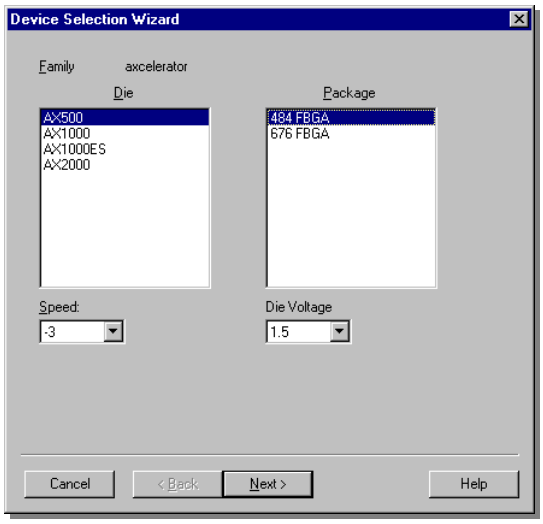
The next step in the design flow is to use Actel's Designer to implement the counter design in an AX500.

Opening Designer R1-2003

Double click the **Designer Place-and-Route** button in the Libero IDE Process window, or right mouse click on *counter16* (*Design Hierarchy* tab) in the Design Explorer Window and select **Run Designer**. This starts the Designer place & route tool.

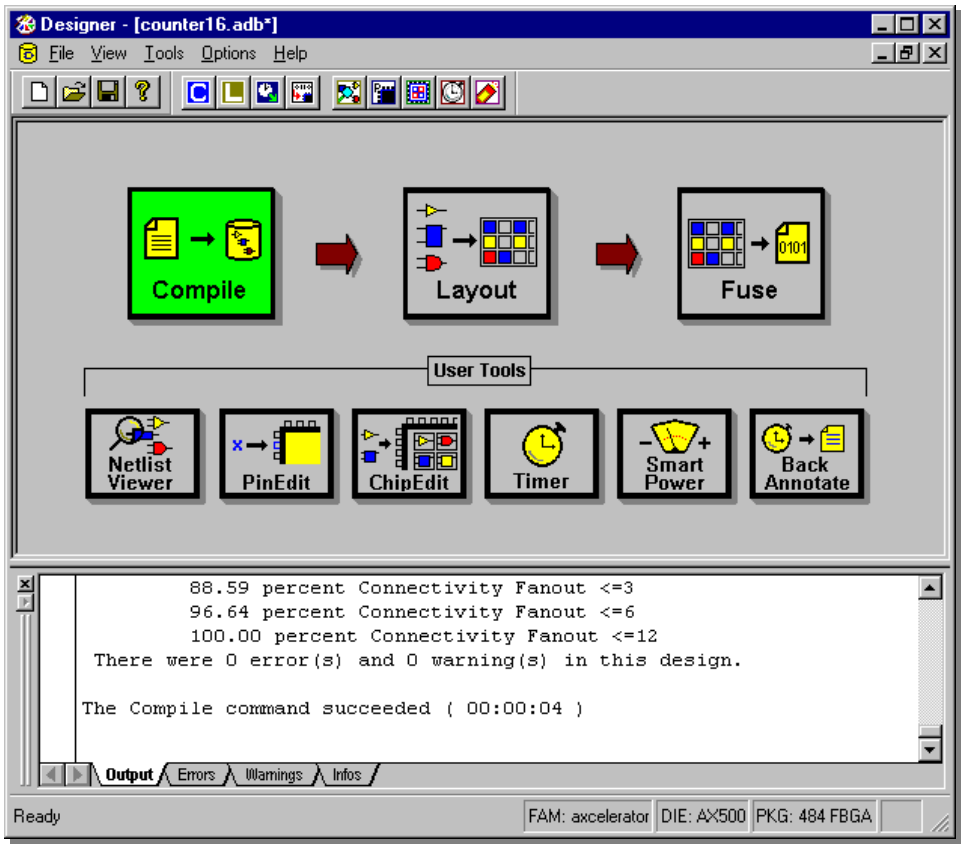


Click the **Compile** button to begin the process. The **Device Selection Wizard** will open. Select the AX500 and the 484FBGA package. Accept the default speed grade and die voltage and click **Next**.

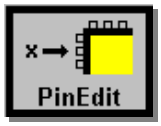


Next, the **Device Selection Wizard – Variations** window opens. Accept the default settings and click **Next**.

The **Device Selection Wizard – Operating Conditions** window opens. Accept the default settings and click **Finish**. Designer will then read the netlist, checking for errors and compile it for the next step. Once completed, the **Compile** button will turn green.



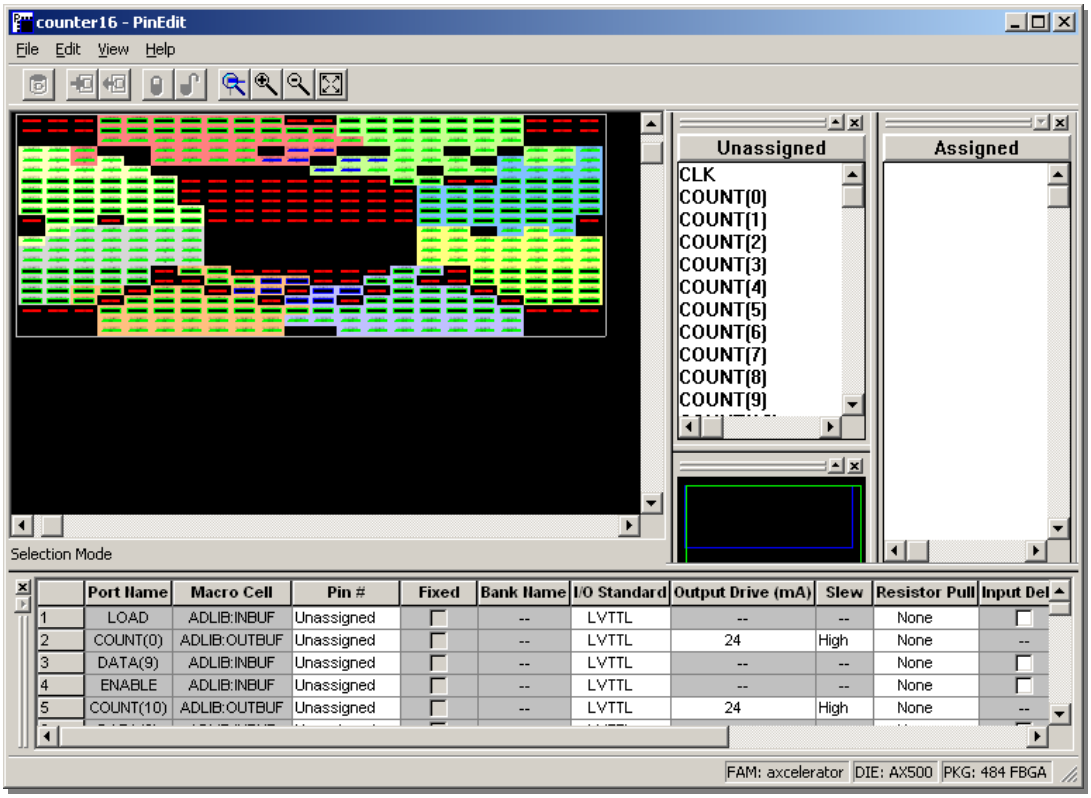
Designer GUI after compiling the counter16 design



Assigning Pin locations

Next use the optional step and define the pin-out of the device *prior* to place and route. The Pin Editor can be used to make and edit I/O macro pin assignments and select I/O pin standards for families which support multiple I/O standards.

Click the **PinEdit** button to open the **Pin Editor**.



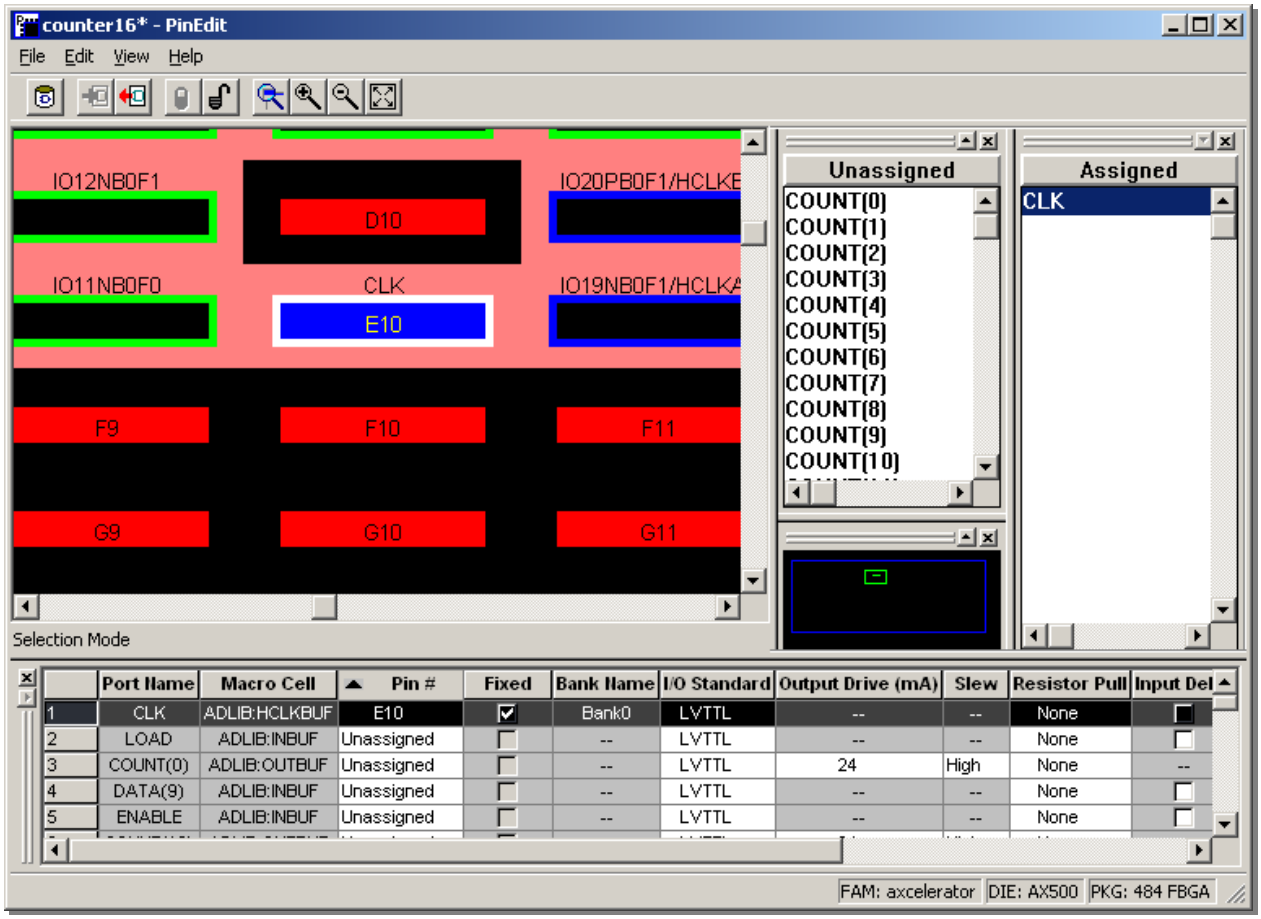
In the **PinEdit** window, the following color-coding scheme is used to denote pin type:

- Package pins shown in green with a black center are available for signals.
- Package pins shown in red are reserved for power and ground.
- Package pins shown in blue with a black center are for reserved pins (e.g. JTAG and Probe pins) and for special pins such as clock inputs.

Selecting a signal pin will cause the pin outline to change from green to white. After assigning signals to a pin, the pin outline will change to yellow indicating a fixed pin assignment.

The Axcelerator Family supports multiple I/O standards and I/Os are grouped onto I/O banks. The I/O banks are color coded for quick identification. Colors can be customized using the Pin Editor Color Manager if desired.

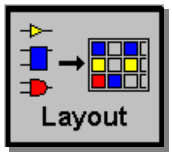
Drag the Signal CLK from the **Unassigned** pane and drop it on the package pin labeled HCLKAP (pin E10). Note that CLK now moves to the **Assigned** pane and the spreadsheet below is updated to reflect the assignment of the CLK signal.



Drag and drop the RESETn signal to the package pin labeled CLKEP (pin V13). Note that each signal moves to the **Assigned** pane and the spreadsheet is updated as it is placed.

Assign other signals to unused green pins. When you are finished placing all the pins, click **File > Close,** to quit **PinEdit** and return to Designer. Answer **Yes** when prompted if you want to save changes you made in Pin Edit.

Layout



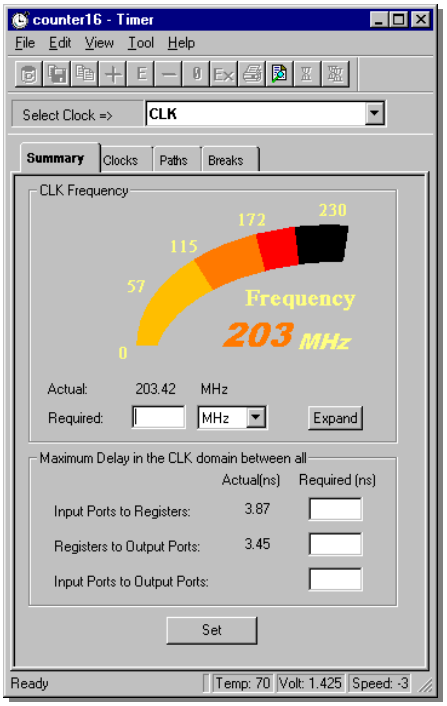
Now you will place and route the counter design – 100% automatically. To invoke the place & route tool, click the Layout button. Accept the default settings in the **Layout Options** window and click **OK**. If you had added timing constraints, the Timing-Driven option would be available. For designs which were previously place & routed that have minor changes, you could select **On** or **Fix** under the **Incremental** options in the Layout window.

Layout will place and route our design, and the Layout button will turn green when completed.

Timer

Next, we will do a quick timing analysis on the counter design. Invoke Timer by clicking the **Timer** icon. The Timer window will open showing a speedometer with the max clock frequency for the counter design. Note the frequency, temp and speed grade. When finished, **File > Close,** to quit.

What frequency did Timer indicate the counter would run?



Exporting a Timing Report

You can export a timing report for the counter design from Designer. From Designer's main menu, select **Tools > Reports**. In the Report Types dialog box, select **Timer** in the drop down menu then click **OK**. In the Timing Report Dialog box, click **Options**.

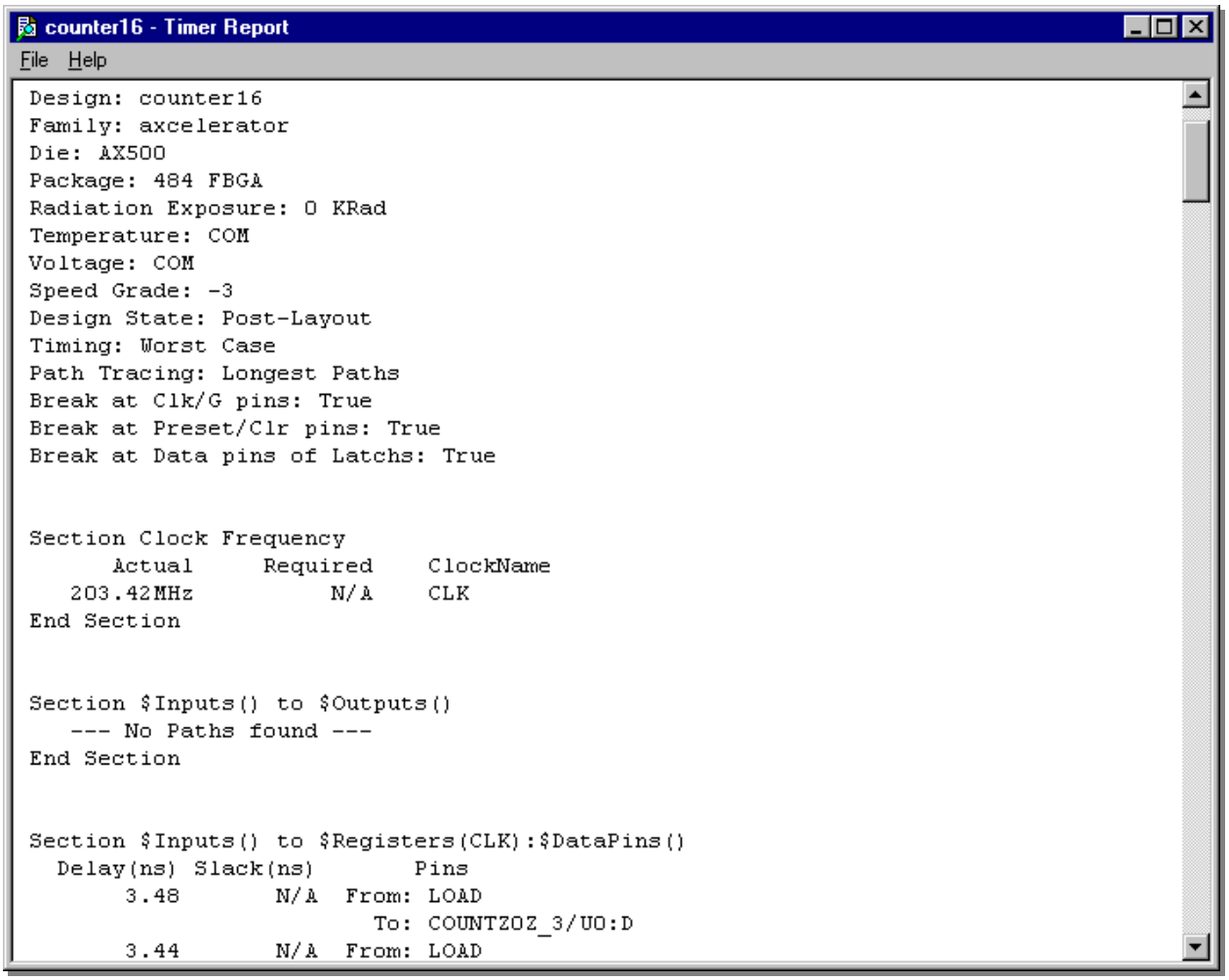
Select sort by **Actual**. In the **Longest/Shortest Path(s)** field, enter **10**. Click **OK**.

Click **OK** in the Timing Report dialog box to accept the other default settings.

A Timing Report Dialog window will open as shown on the next page.

In the Timing Report window, select **File > Save As**. Name the file **counter16.*rpt***.

Select **File > Close** to close the Timing Report window.

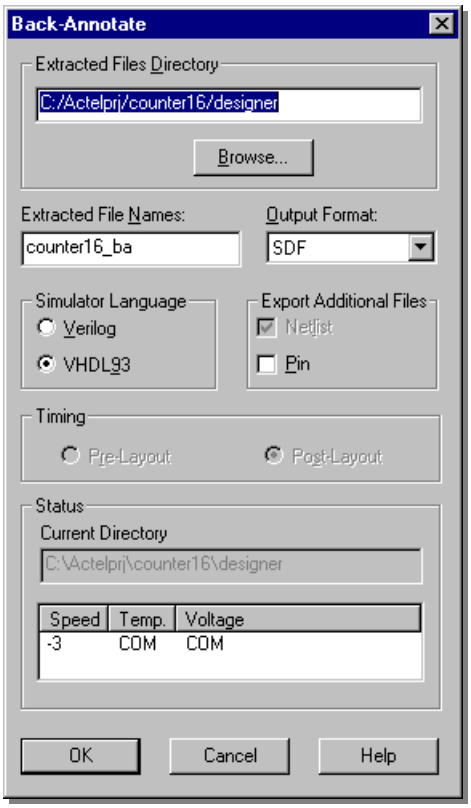


Timing report for the counter

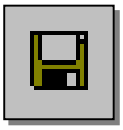
Back-annotate

To do timing simulation using post-layout results, you need to generate the necessary files: post-placement netlist and an SDF (Standard Delay Format) file with actual timing numbers from our place & route. Click the **Back-Annotate** button and the Back-Annotate window will open.

Accept all defaults and click **OK** (see figure to right).

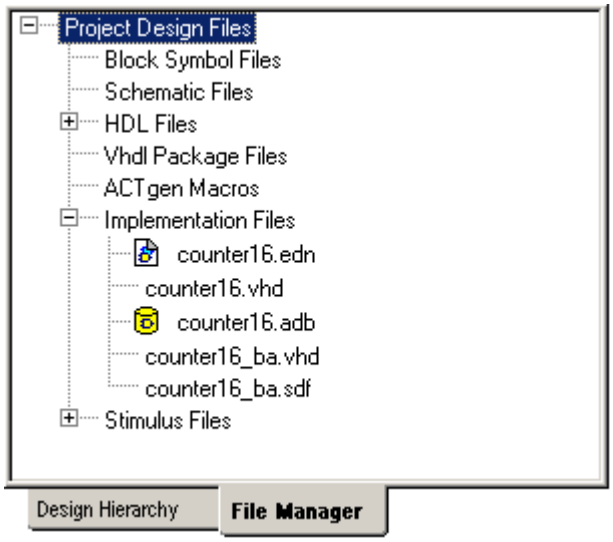


Saving your design files



Be sure the save your work! When finished, click **File > Save** then **File > Exit,** to close Designer.

After exiting Designer, the Actel database (*counter16.adb*) and the timing information (*counter16_ba.sdf*) will be visible in the Libero IDE Design Explorer window on the File manager tab under Implementation Files.



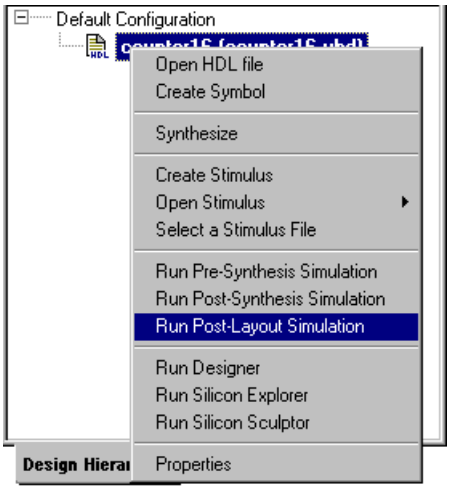
Section 6

Back-Annotated Timing Simulation

Invoking the Simulator

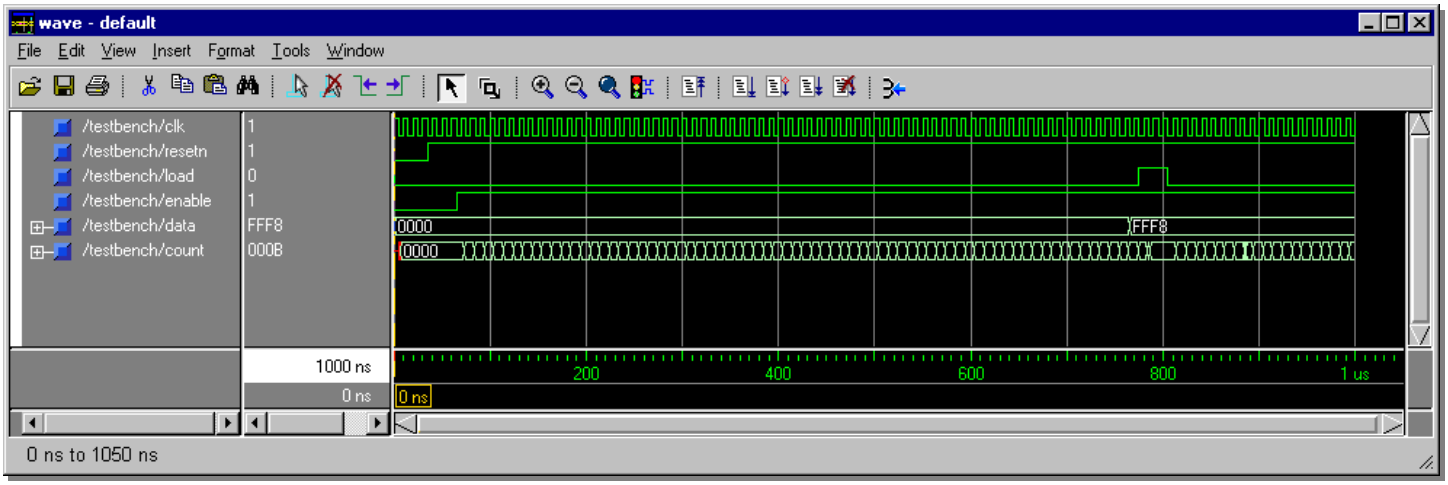
In this section, you will simulate the structural VHDL netlist of the counter using the VHDL testbench that was created in section 2 and the actual timing numbers (SDF) exported from Designer in section 5.

Click the **ModelSim Simulation** button in the Libero IDE Process window, or right mouse click on *counter16* (*Design Hierarchy* tab) in the Design Explorer Window and select **Run Post-Layout Simulation**.



The ModelSim for Actel VHDL Simulator will open and compile the source file and the testbench.

Observe the waveforms in the Wave window and confirm that the counter operates correctly and your results match the results from Sections 2 and 4. Change the radix of the signals and use the zoom controls as necessary to match the results shown below.

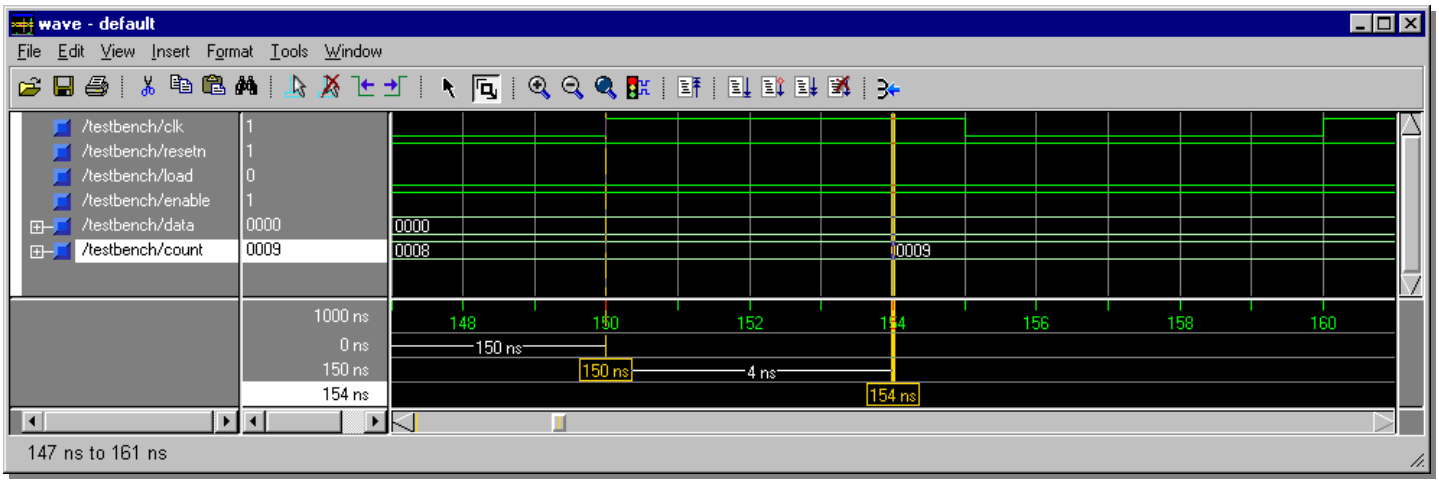


Timing analysis

Using the zoom controls and the cursors in the Wave window you can measure the length of time it takes for COUNT to change after a rising clock edge.

You will need to zoom in to an area in order to measure the time.

To make a time measurement between two edges, add cursors to the Wave window by clicking **Insert > Cursor** from the Wave menu. Drag one of the cursors to a rising edge of **clk** and drag the other cursor to the following transition on **count**. The difference between the cursors will be visible at the bottom of the Wave window. Note the time.



1. What was the time between the rising clock edge and COUNT changing?

2. What does this number represent?

Close ModelSim for Actelby clicking **File > Quit** from the main menu. Select **Yes** when prompted if you are sure you want to quit.

Close Libero IDE by clicking **File > Exit** from the main menu.

APPENDIX A: VHDL SOURCE CODE

```
-- 16 bit loadable counter with enable and asynchronous reset
-- Actel Corporation
-- July 25, 2002

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity counter16 is
port (CLK, RESETn, LOAD, ENABLE: in std_logic;
        DATA: in std_logic_vector(15 downto 0);
        COUNT: out std_logic_vector(15 downto 0));
end counter16;

architecture RTL of counter16 is
signal COUNT_int: std_logic_vector(15 downto 0);

begin

process (RESETn, CLK)
begin
  if (RESETn = '0') then
      COUNT_int <= (others => '0');
  elsif (CLK 'event and CLK = '1') then
      if (LOAD = '1') then
        COUNT_int <= DATA;
      elsif (ENABLE = '1') then
        COUNT_int <= COUNT_int + 1;
      end if;
  end if;
end process;

COUNT <= COUNT_int;

end RTL;
```

Appendix B: VHLD Testbench

```
-- Generated by WaveFormer Lite Version 8.9 at 17:44:57 on 10/25/2002
library ieee, std;
-- Libraries used by model under test
use IEEE.std_logic_1164.all;
use IEEE.std_logic_unsigned.all;
-- End of libraries used by model under test

entity stimulus is
  port(
       CLK          : out std_logic;
       RESETn             : out std_logic;
       LOAD         : out std_logic;
       ENABLE             : out std_logic;
       DATA         : out std_logic_vector(15 downto 0);
       COUNT        : in std_logic_vector(15 downto 0)
       );
end stimulus;

architecture GeneratedCode of stimulus is
begin

CLK_process : process
  variable tb_stop_time : time := 1201 ns;
  variable CLK_Offset : time := 0 ns;
  variable CLK_Period : time := 10 ns;
  variable CLK_MinLH : time := 0 ns;
  variable CLK_MaxLH : time := 0 ns;
  variable CLK_MinHL : time := 0 ns;
  variable CLK_MaxHL : time := 0 ns;
  variable CLK_JRise : time := 0 ns;
  variable CLK_JFall : time := 0 ns;
  variable CLK_Duty : time := 50 ns;
  variable CLK_high : time;
  variable CLK_low : time;
begin
  CLK_high := CLK_Period * (CLK_Duty / ns) / 100;
  CLK_low := CLK_Period - CLK_high;
  CLK <= '0';
  if (CLK_Offset + (CLK_MinLH - CLK_JRise/2) < 0 ns) then
    assert FALSE report "Clock offset is less than 0 for CLK. This could be
caused by jitter. Increase offset to get rid of this error." severity
FAILURE;
  else
    wait for CLK_Offset + (CLK_MinLH - CLK_JRise/2);
    while (now < tb_stop_time) loop
      CLK <= '1';
      wait for (CLK_high - (CLK_MaxLH + CLK_JRise/2) + (CLK_MinHL -
CLK_JFall/2));
      CLK <= '0';
      wait for (CLK_low - (CLK_MaxHL + CLK_JFall/2) + (CLK_MinLH -
CLK_JRise/2));
```

```
    end loop;
  end if;
end process;

  process
  begin
        RESETn    <=    '0';
        LOAD      <=    '0';
        ENABLE    <=    '0';
        DATA      <=    x"0000";
      wait for 35 ns;   -- Accumulated time = 35 ns

        RESETn    <=    '1';
      wait for 30 ns;   -- Accumulated time = 65 ns

        ENABLE    <=    '1';
      wait for 700 ns;   -- Accumulated time = 765 ns

        DATA      <=    x"FFF8";
      wait for 10 ns;   -- Accumulated time = 775 ns

        LOAD      <=    '1';
      wait for 30 ns;   -- Accumulated time = 805 ns

        LOAD      <=    '0';
      wait for 396 ns;   -- Accumulated time = 1201 ns

      wait;
  end process;

end GeneratedCode;

--Top Level Test Bench Module
  -- Contains an instance of the Stimulus Module and an instance of the
Product Module
library ieee, std;
-- Libraries used by model under test
use IEEE.std_logic_1164.all;
use IEEE.std_logic_unsigned.all;
-- End of libraries used by model under test

use work.all;

entity testbench is
  end testbench;

architecture tbGeneratedCode of testbench is
   -- Component declaration for the stimulus module
   component stimulus
    port(
      CLK         : out std_logic;
      RESETn            : out std_logic;
      LOAD        : out std_logic;
      ENABLE            : out std_logic;
```

```
      DATA        : out std_logic_vector(15 downto 0);
      COUNT       : in std_logic_vector(15 downto 0)
        );
   end component;

   -- Component declaration for the product module
   component counter
    port(
      CLK    : in  std_logic;
      RESETn       : in  std_logic;
      LOAD   : in  std_logic;
      ENABLE       : in  std_logic;
      DATA   : in  std_logic_vector(15 downto 0);
      COUNT  : out       std_logic_vector(15 downto 0)
        );
   end component;
   -- Signal Declarations for the test bench module
    signal        CLK              : std_logic;
    signal        RESETn                 : std_logic;
    signal        LOAD             : std_logic;
    signal        ENABLE                 : std_logic;
    signal        DATA             : std_logic_vector(15 downto 0);
    signal        COUNT            : std_logic_vector(15 downto 0);

   -- Ports are connected by matching the port names of the Test Module
   begin
     stimulus_0: stimulus
       port map(
                 CLK,
                 RESETn,
                 LOAD,
                 ENABLE,
                 DATA,
                 COUNT
                   );
    counter_0 : counter
      port map(
                 CLK => CLK,
                 RESETn => RESETn,
                 LOAD => LOAD,
                 ENABLE => ENABLE,
                 DATA => DATA,
                 COUNT => COUNT
                 );
end tbGeneratedCode;
```