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# Table of Contents

## Chapter 1
**Introduction** ................................................................. 7
- Assumptions ................................................................. 7
- Before you Begin ............................................................. 7
- Example Designs .............................................................. 7

## Chapter 2
**Conceptual Overview** ....................................................... 9
- Basic Simulation Flow ...................................................... 9
- Project Flow ................................................................. 10
- Multiple Library Flow .................................................... 11
- Debugging Tools ............................................................ 12

## Chapter 3
**Basic Simulation** ............................................................... 13
- Create the Working Design Library ................................... 13
- Compile the Design Units ............................................... 15
- Load the Design ............................................................ 16
- Run the Simulation ......................................................... 19
- Set Breakpoints and Step through the Source ..................... 20

## Chapter 4
**Projects** ........................................................................... 25
- Create a New Project ....................................................... 25
  - Add Objects to the Project ........................................... 26
  - Changing Compile Order (VHDL) .................................. 28
  - Compile the Design ...................................................... 29
  - Load the Design .......................................................... 30
- Organizing Projects with Folders ...................................... 31
  - Add Folders ............................................................... 31
  - Moving Files to Folders ............................................... 33
- Simulation Configurations ............................................... 33

## Chapter 5
**Working With Multiple Libraries** ....................................... 37
- Creating the Resource Library .......................................... 37
- Creating the Project ....................................................... 39
- Linking to the Resource Library ....................................... 40
  - Verilog ..................................................................... 40
  - VHDL ..................................................................... 41
- Linking to a Resource Library .......................................... 42
Table of Contents

Permanentely Mapping VHDL Resource Libraries ................................. 43

Chapter 6
Analyzing Waveforms ................................................................. 45
  Loading a Design ................................................................. 46
  Add Objects to the Wave Window ........................................... 46
  Zooming the Waveform Display ............................................... 47
  Using Cursors in the Wave Window .......................................... 48
    Working with a Single Cursor ............................................... 48
    Working with Multiple Cursors ........................................... 50

Chapter 7
Viewing And Initializing Memories ................................................ 53
  View a Memory and its Contents ............................................ 54
    Navigate Within the Memory ............................................... 58
  Export Memory Data to a File ................................................ 60
  Initialize a Memory .............................................................. 61
  Interactive Debugging Commands ............................................. 64

Chapter 8
Automating Simulation ................................................................. 69
  Creating a Simple DO File ...................................................... 69
  Running in Command-Line Mode ............................................... 70
  Using Tcl with the Simulator .................................................. 73

Index

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List of Figures

Figure 2-1. Basic Simulation Flow - Overview Lab ............................................. 9
Figure 2-2. Project Flow ................................................................................. 11
Figure 2-3. Multiple Library Flow................................................................. 12
Figure 3-1. The Create a New Library Dialog ................................................ 14
Figure 3-2. work Library Added to the Library Window ............................... 15
Figure 3-3. Compile Source Files Dialog ....................................................... 16
Figure 3-4. Verilog Modules Compiled into work Library ............................. 16
Figure 3-5. Loading Design with Start Simulation Dialog ........................... 17
Figure 3-6. The Design Hierarchy ................................................................. 18
Figure 3-7. The Object Window and Processes Window .............................. 18
Figure 3-8. Using the Popup Menu to Add Signals to Wave Window .......... 19
Figure 3-9. Waves Drawn in Wave Window .................................................... 20
Figure 3-10. Setting Breakpoint in Source Window ...................................... 21
Figure 3-11. Setting Restart Functions ......................................................... 21
Figure 3-12. Blue Arrow Indicates Where Simulation Stopped ..................... 22
Figure 3-13. Values Shown in Objects Window ............................................ 22
Figure 3-14. Parameter Name and Value in Source Examine Window ........ 23
Figure 4-1. Create Project Dialog - Project Lab ............................................ 26
Figure 4-2. Adding New Items to a Project .................................................... 27
Figure 4-3. Add file to Project Dialog ........................................................... 27
Figure 4-4. Newly Added Project Files Display a '?' for Status .................... 28
Figure 4-5. Compile Order Dialog ............................................................... 29
Figure 4-6. Library Window with Expanded Library ..................................... 30
Figure 4-7. Structure(sim) window for a Loaded Design ............................... 30
Figure 4-8. Adding New Folder to Project .................................................... 31
Figure 4-9. A Folder Within a Project ........................................................... 32
Figure 4-10. Creating Subfolder ................................................................. 32
Figure 4-11. A folder with a Sub-folder ........................................................ 32
Figure 4-12. Changing File Location via the Project Compiler Settings Dialog 33
Figure 4-13. Simulation Configuration Dialog ............................................ 34
Figure 4-14. A Simulation Configuration in the Project window .................... 35
Figure 4-15. Transcript Shows Options for Simulation Configurations .......... 35
Figure 5-1. Creating New Resource Library ............................................... 38
Figure 5-2. Compiling into the Resource Library ......................................... 39
Figure 5-3. Verilog Simulation Error Reported in Transcript ........................ 41
Figure 5-4. VHDL Simulation Warning Reported in Main Window ............. 42
Figure 5-5. Specifying a Search Library in the Simulate Dialog ................... 43
Figure 6-1. Panes of the Wave Window ....................................................... 45
Figure 6-2. Zooming in with the Mouse Pointer .......................................... 48
Figure 6-3. Working with a Single Cursor in the Wave Window .................. 49
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 6-4</td>
<td>Renaming a Cursor</td>
<td>50</td>
</tr>
<tr>
<td>Figure 6-5</td>
<td>Interval Measurement Between Two Cursors</td>
<td>50</td>
</tr>
<tr>
<td>Figure 6-6</td>
<td>A Locked Cursor in the Wave Window</td>
<td>51</td>
</tr>
<tr>
<td>Figure 7-1</td>
<td>The Memory List in the Memory window</td>
<td>54</td>
</tr>
<tr>
<td>Figure 7-2</td>
<td>Verilog Memory Data Window</td>
<td>55</td>
</tr>
<tr>
<td>Figure 7-3</td>
<td>VHDL Memory Data Window</td>
<td>55</td>
</tr>
<tr>
<td>Figure 7-4</td>
<td>Verilog Data After Running Simulation</td>
<td>56</td>
</tr>
<tr>
<td>Figure 7-5</td>
<td>VHDL Data After Running Simulation</td>
<td>56</td>
</tr>
<tr>
<td>Figure 7-6</td>
<td>Changing the Address Radix</td>
<td>57</td>
</tr>
<tr>
<td>Figure 7-7</td>
<td>New Address Radix and Line Length (Verilog)</td>
<td>57</td>
</tr>
<tr>
<td>Figure 7-8</td>
<td>New Address Radix and Line Length (VHDL)</td>
<td>58</td>
</tr>
<tr>
<td>Figure 7-9</td>
<td>Goto Dialog</td>
<td>58</td>
</tr>
<tr>
<td>Figure 7-10</td>
<td>Editing the Address Directly</td>
<td>59</td>
</tr>
<tr>
<td>Figure 7-11</td>
<td>Searching for a Specific Data Value</td>
<td>59</td>
</tr>
<tr>
<td>Figure 7-12</td>
<td>Export Memory Dialog</td>
<td>60</td>
</tr>
<tr>
<td>Figure 7-13</td>
<td>Import Memory Dialog</td>
<td>62</td>
</tr>
<tr>
<td>Figure 7-14</td>
<td>Initialized Memory from File and Fill Pattern</td>
<td>63</td>
</tr>
<tr>
<td>Figure 7-15</td>
<td>Data Increments Starting at Address 251</td>
<td>64</td>
</tr>
<tr>
<td>Figure 7-16</td>
<td>Original Memory Content</td>
<td>65</td>
</tr>
<tr>
<td>Figure 7-17</td>
<td>Changing Memory Content for a Range of Addresses**OK</td>
<td>65</td>
</tr>
<tr>
<td>Figure 7-18</td>
<td>Random Content Generated for a Range of Addresses</td>
<td>66</td>
</tr>
<tr>
<td>Figure 7-19</td>
<td>Changing Memory Contents by Highlighting</td>
<td>66</td>
</tr>
<tr>
<td>Figure 7-20</td>
<td>Entering Data to Change**OK</td>
<td>67</td>
</tr>
<tr>
<td>Figure 7-21</td>
<td>Changed Memory Contents for the Specified Addresses</td>
<td>67</td>
</tr>
<tr>
<td>Figure 8-1</td>
<td>Wave Window After Running the DO File</td>
<td>70</td>
</tr>
<tr>
<td>Figure 8-2</td>
<td>The counter.wlf Dataset in the Main Window Workspace</td>
<td>72</td>
</tr>
</tbody>
</table>
Assumptions

Using this tutorial for ModelSim™ is based on the following assumptions:

- You are familiar with how to use your operating system, along with its window management system and graphical interface: OpenWindows, OSF/Motif, CDE, KDE, GNOME, or Microsoft Windows XP.

- You have a working knowledge of the language in which your design and/or test bench is written (such as VHDL, Verilog). Although ModelSim is an excellent application to use while learning HDL concepts and practices, this tutorial is not intended to support that goal.

Before you Begin

Preparation for some of the lessons leaves certain details up to you. You will decide the best way to create directories, copy files, and execute programs within your operating system. (When you are operating the simulator within ModelSim’s GUI, the interface is consistent for all platforms.)

Examples show Windows path separators - use separators appropriate for your operating system when trying the examples.

Example Designs

ModelSim comes with Verilog and VHDL versions of the designs used in these lessons. This allows you to do the tutorial regardless of which license type you have. Though we have tried to minimize the differences between the Verilog and VHDL versions, we could not do so in all cases. In cases where the designs differ (e.g., line numbers or syntax), you will find language-specific instructions. Follow the instructions that are appropriate for the language you use.
Chapter 2
Conceptual Overview

Introduction

ModelSim is a verification and simulation tool for VHDL, Verilog, SystemVerilog, and mixed-language designs.

This lesson provides a brief conceptual overview of the ModelSim simulation environment. It is divided into four topics, which you will learn more about in subsequent lessons.

- Basic simulation flow — Refer to Chapter 3, Basic Simulation.
- Project flow — Refer to Chapter 4, Projects.
- Multiple library flow — Refer to Chapter 5, Working With Multiple Libraries.
- Debugging tools — Refer to remaining lessons.

Basic Simulation Flow

The following diagram shows the basic steps for simulating a design in ModelSim.

**Figure 2-1. Basic Simulation Flow - Overview Lab**

```
Create a working library

Compile design files

Load and Run simulation

Debug results
```
Conceptual Overview

Project Flow

- Creating the Working Library
  In ModelSim, all designs are compiled into a library. You typically start a new simulation in ModelSim by creating a working library called "work," which is the default library name used by the compiler as the default destination for compiled design units.

- Compiling Your Design
  After creating the working library, you compile your design units into it. The ModelSim library format is compatible across all supported platforms. You can simulate your design on any platform without having to recompile your design.

- Loading the Simulator with Your Design and Running the Simulation
  With the design compiled, you load the simulator with your design by invoking the simulator on a top-level module (Verilog) or a configuration or entity/architecture pair (VHDL).

  Assuming the design loads successfully, the simulation time is set to zero, and you enter a run command to begin simulation.

- Debugging Your Results
  If you don’t get the results you expect, you can use ModelSim’s robust debugging environment to track down the cause of the problem.

Project Flow

A project is a collection mechanism for an HDL design under specification or test. Even though you don’t have to use projects in ModelSim, they may ease interaction with the tool and are useful for organizing files and specifying simulation settings.

The following diagram shows the basic steps for simulating a design within a ModelSim project.
As you can see, the flow is similar to the basic simulation flow. However, there are two important differences:

- You do not have to create a working library in the project flow; it is done for you automatically.
- Projects are persistent. In other words, they will open every time you invoke ModelSim unless you specifically close them.

Multiple Library Flow

ModelSim uses libraries in two ways: 1) as a local working library that contains the compiled version of your design; 2) as a resource library. The contents of your working library will change as you update your design and recompile. A resource library is typically static and serves as a parts source for your design. You can create your own resource libraries, or they may be supplied by another design team or a third party (e.g., a silicon vendor).

You specify which resource libraries will be used when the design is compiled, and there are rules to specify in which order they are searched. A common example of using both a working library and a resource library is one where your gate-level design and test bench are compiled into the working library, and the design references gate-level models in a separate resource library.

The diagram below shows the basic steps for simulating with multiple libraries.
You can also link to resource libraries from within a project. If you are using a project, you would replace the first step above with these two steps: create the project and add the test bench to the project.

**Debugging Tools**

ModelSim offers numerous tools for debugging and analyzing your design. Several of these tools are covered in subsequent lessons, including:

- Using projects
- Working with multiple libraries
- Setting breakpoints and stepping through the source code
- Viewing waveforms and measuring time
- Viewing and initializing memories
- Creating stimulus with the Waveform Editor
- Automating simulation
Chapter 3
Basic Simulation

Introduction

In this lesson you will go step-by-step through the basic simulation flow:

1. Create the Working Design Library
2. Compile the Design Units
3. Load the Design
4. Run the Simulation

Design Files for this Lesson

The sample design for this lesson is a simple 8-bit, binary up-counter with an associated test bench. The pathnames are as follows:

Verilog – `<install_dir>/examples/tutorials/verilog/basicSimulation/counter.v` and `tcounter.v`

VHDL – `<install_dir>/examples/tutorials/vhdl/basicSimulation/counter.vhd` and `tcounter.vhd`

This lesson uses the Verilog files `counter.v` and `tcounter.v`. If you have a VHDL license, use `counter.vhd` and `tcounter.vhd` instead. Or, if you have a mixed license, feel free to use the Verilog test bench with the VHDL counter or vice versa.

Related Reading


Create the Working Design Library

Before you can simulate a design, you must first create a library and compile the source code into that library.

1. Create a new directory and copy the design files for this lesson into it.

Start by creating a new directory for this exercise (in case other users will be working with these lessons).
Basic Simulation
Create the Working Design Library

**Verilog:** Copy `counter.v` and `tcounter.v` files from
`/<install_dir>/examples/tutorials/verilog/basicSimulation` to the new directory.

**VHDL:** Copy `counter.vhd` and `tcounter.vhd` files from
`/<install_dir>/examples/tutorials/vhdl/basicSimulation` to the new directory.

2. Start ModelSim if necessary.
   a. Type `vsim` at a UNIX shell prompt or use the ModelSim icon in Windows.
      
      Upon opening ModelSim for the first time, you will see the Welcome to ModelSim dialog. Click Close.
   b. Select File > Change Directory and change to the directory you created in step 1.

3. Create the working library.
   a. Select File > New > Library.
      
      This opens a dialog where you specify physical and logical names for the library (Figure 3-1). You can create a new library or map to an existing library. We’ll be doing the former.

      **Figure 3-1. The Create a New Library Dialog**

      ![Create a New Library Dialog](image)

      b. Type `work` in the Library Name field (if it isn’t already entered automatically).
      c. Click OK.
         
         ModelSim creates a directory called `work` and writes a specially-formatted file named `_info` into that directory. The `_info` file must remain in the directory to distinguish it as a ModelSim library. Do not edit the folder contents from your operating system; all changes should be made from within ModelSim.
ModelSim also adds the library to the Library window (Figure 3-2) and records the library mapping for future reference in the ModelSim initialization file (modelsim.ini).

**Figure 3-2. work Library Added to the Library Window**

When you pressed OK in step 3c above, the following was printed to the Transcript window:

```
  vlib work
  vmap work work
```

These two lines are the command-line equivalents of the menu selections you made. Many command-line equivalents will echo their menu-driven functions in this fashion.

**Compile the Design Units**

With the working library created, you are ready to compile your source files.

You can compile by using the menus and dialogs of the graphic interface, as in the Verilog example below, or by entering a command at the ModelSim> prompt.

1. Compile `counter.v` and `tcounter.v`.
   a. Select **Compile > Compile**. This opens the Compile Source Files dialog (Figure 3-3).

      If the Compile menu option is not available, you probably have a project open. If so, close the project by making the Library window active and selecting File > Close from the menus.

   b. Select both `counter.v` and `tcounter.v` modules from the Compile Source Files dialog and click **Compile**. The files are compiled into the `work` library.

   c. When compile is finished, click **Done**.
Basic Simulation
Load the Design

2. View the compiled design units.
   a. In the Library window, click the '+' icon next to the work library and you will see two design units (Figure 3-4). You can also see their types (Modules, Entities, etc.) and the path to the underlying source files.

![Figure 3-4. Verilog Modules Compiled into work Library](image)

Load the Design

1. Load the test_counter module into the simulator.
   a. In the Library window, click the '+' sign next to the work library to show the files contained there.
   b. Double-click test_counter to load the design.
You can also load the design by selecting **Simulate > Start Simulation** in the menu bar. This opens the Start Simulation dialog. With the Design tab selected, click the ‘+’ sign next to the work library to see the `counter` and `test_counter` modules. Select the `test_counter` module and click OK (Figure 3-5).

**Figure 3-5. Loading Design with Start Simulation Dialog**

When the design is loaded, a Structure window opens (labeled `sim`). This window displays the hierarchical structure of the design as shown in Figure 3-6. You can navigate within the design hierarchy in the Structure (`sim`) window by clicking on any line with a ‘+’ (expand) or ‘-’ (contract) icon.
In addition, an Objects window and a Processes window opens (Figure 3-7). The Objects window shows the names and current values of data objects in the current region selected in the Structure (sim) window. Data objects include signals, nets, registers, constants and variables not declared in a process, generics, parameters.

The Processes window displays a list of HDL processes in one of four viewing modes: Active, In Region, Design, and Hierarchical. The Design view mode is intended for primary navigation of ESL (Electronic System Level) designs where processes are a foremost consideration. By default, this window displays the active processes in your simulation (Active view mode).
Run the Simulation

We’re ready to run the simulation. But before we do, we’ll open the Wave window and add signals to it.

1. Open the Wave window.
   a. Enter `view wave` at the command line.

      The Wave window opens in the right side of the Main window. Resize it so it is visible.

      You can also use the View > Wave menu selection to open a Wave window. The Wave window is just one of several debugging windows available on the View menu.

2. Add signals to the Wave window.
   a. In the Structure (sim) window, right-click `test_counter` to open a popup context menu.
   b. Select AddTo > Wave > All items in region (Figure 3-8).

      All signals in the design are added to the Wave window.

3. Run the simulation.
   a. Click the Run icon.

      The simulation runs for 100 ns (the default simulation length) and waves are drawn in the Wave window.
   b. Enter `run 500` at the VSIM> prompt in the Transcript window.
The simulation advances another 500 ns for a total of 600 ns (Figure 3-9).

**Figure 3-9. Waves Drawn in Wave Window**

```
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>/test_counter/clk</td>
<td>0</td>
</tr>
<tr>
<td>/test_counter/reset</td>
<td>0</td>
</tr>
<tr>
<td>/test_counter/count</td>
<td>00101011</td>
</tr>
</tbody>
</table>
```

![Wave Window](image)

- Click the Run -All icon on the Main or Wave window toolbar.

The simulation continues running until you execute a break command or it hits a statement in your code (e.g., a Verilog $stop statement) that halts the simulation.

- Click the Break icon to stop the simulation.

### Set Breakpoints and Step through the Source

Next you will take a brief look at one interactive debugging feature of the ModelSim environment. You will set a breakpoint in the Source window, run the simulation, and then step through the design under test. Breakpoints can be set only on executable lines, which are indicated with red line numbers.

1. Open `counter.v` in the Source window.
   - Select View > Files to open the Files window.
   - Click the + sign next to the sim filename to see the contents of `vsim.wlf` dataset.
   - Double-click `counter.v` (or `counter.vhd` if you are simulating the VHDL files) to open the file in the Source window.

2. Set a breakpoint on line 36 of `counter.v` (or, line 39 of `counter.vhd` for VHDL).
   - Scroll to line 36 and click in the Ln# (line number) column next to the line number.

A red ball appears in the line number column at line number 36 (Figure 3-10), indicating that a breakpoint has been set.
3. Disable, enable, and delete the breakpoint.
   a. Click the red ball to disable the breakpoint. It will become a black ball.
   b. Click the black ball again to re-enable the breakpoint. It will become a red ball.
   c. Click the red ball with your right mouse button and select **Remove Breakpoint 36**.
   d. Click in the line number column next to line number 36 again to re-create the breakpoint.

4. Restart the simulation.
   a. Click the Restart icon to reload the design elements and reset the simulation time to zero.

   The Restart dialog that appears gives you options on what to retain during the restart (**Figure 3-11**).

   

4. Restart the simulation.
   a. Click the Restart icon to reload the design elements and reset the simulation time to zero.

   The Restart dialog that appears gives you options on what to retain during the restart (**Figure 3-11**).

   

b. Click the **Restart** button in the Restart dialog.
c. Click the Run -All icon.

The simulation runs until the breakpoint is hit. When the simulation hits the breakpoint, it stops running, highlights the line with a blue arrow in the Source view (Figure 3-12), and issues a Break message in the Transcript window.

Figure 3-12. Blue Arrow Indicates Where Simulation Stopped.

When a breakpoint is reached, typically you want to know one or more signal values. You have several options for checking values:

- look at the values shown in the Objects window (Figure 3-13)

Figure 3-13. Values Shown in Objects Window

- set your mouse pointer over a variable in the Source window and a yellow box will appear with the variable name and the value of that variable at the time of the selected cursor in the Wave window

- highlight a signal, parameter, or variable in the Source window, right-click it, and select Examine from the pop-up menu to display the variable and its current value in a Source Examine window (Figure 3-14)
5. Try out the step commands.
   a. Click the Step Into icon on the Step toolbar.
      This single-steps the debugger.
      Experiment on your own. Set and clear breakpoints and use the Step, Step Over, and Continue Run commands until you feel comfortable with their operation.

Lesson Wrap-Up

This concludes this lesson. Before continuing we need to end the current simulation.

1. Select Simulate > End Simulation.
2. Click Yes when prompted to confirm that you wish to quit simulating.
Basic Simulation

Set Breakpoints and Step through the Source
Chapter 4
Projects

Introduction

In this lesson you will practice creating a project.

At a minimum, projects contain a work library and a session state that is stored in an .mpf file. A project may also consist of:

- HDL source files or references to source files
- other files such as READMEs or other project documentation
- local libraries
- references to global libraries

Design Files for this Lesson

The sample design for this lesson is a simple 8-bit, binary up-counter with an associated test bench. The pathnames are as follows:

**Verilog** – `<install_dir>/examples/tutorials/verilog/projects/counter.v` and `tcounter.v`

**VHDL** – `<install_dir>/examples/tutorials/vhdl/projects/counter.vhd` and `tcounter.vhd`

This lesson uses the Verilog files `tcounter.v` and `counter.v`. If you have a VHDL license, use `tcounter.vhd` and `counter.vhd` instead.

Related Reading


Create a New Project

1. Create a new directory and copy the design files for this lesson into it.

   Start by creating a new directory for this exercise (in case other users will be working with these lessons).

   **Verilog**: Copy `counter.v` and `tcounter.v` files from `/<install_dir>/examples/tutorials/verilog/projects` to the new directory.

   **VHDL**: Copy `counter.vhd` and `tcounter.vhd` files from `/<install_dir>/examples/tutorials/vhdl/projects` to the new directory.
Projects
Create a New Project

2. If you just finished the previous lesson, ModelSim should already be running. If not, start ModelSim.
   a. Type `vsim` at a UNIX shell prompt or use the ModelSim icon in Windows.
   b. Select `File > Change Directory` and change to the directory you created in step 1.
3. Create a new project.
   a. Select `File > New > Project` (Main window) from the menu bar.
      This opens the Create Project dialog where you can enter a Project Name, Project Location (i.e., directory), and Default Library Name (Figure 4-1). You can also reference library settings from a selected .ini file or copy them directly into the project. The default library is where compiled design units will reside.
   b. Type `test` in the Project Name field.
   c. Click the **Browse** button for the Project Location field to select a directory where the project file will be stored.
   d. Leave the Default Library Name set to `work`.
   e. Click **OK**.

![Figure 4-1. Create Project Dialog - Project Lab](image)

Add Objects to the Project

Once you click **OK** to accept the new project settings, a blank Project window and the “Add items to the Project” dialog will appear (Figure 4-2). From the dialog you can create a new design file, add an existing file, add a folder for organization purposes, or create a simulation configuration (discussed below).
Figure 4-2. Adding New Items to a Project

1. Add two existing files.

   a. Click **Add Existing File**.

      This opens the Add file to Project dialog (Figure 4-3). This dialog lets you browse to find files, specify the file type, specify a folder to which the file will be added, and identify whether to leave the file in its current location or to copy it to the project directory.

Figure 4-3. Add file to Project Dialog

   b. Click the **Browse** button for the File Name field. This opens the “Select files to add to project” dialog and displays the contents of the current directory.

   c. **Verilog**: Select `counter.v` and `tcounter.v` and click **Open**.

      **VHDL**: Select `counter.vhd` and `tcounter.vhd` and click **Open**.

      This closes the “Select files to add to project” dialog and displays the selected files in the “Add file to Project” dialog (Figure 4-3).

   d. Click **OK** to add the files to the project.
Projects
Create a New Project

e. Click **Close** to dismiss the Add items to the Project dialog.

You should now see two files listed in the Project window (Figure 4-4). Question-mark icons in the Status column indicate that the file has not been compiled or that the source file has changed since the last successful compile. The other columns identify file type (e.g., Verilog or VHDL), compilation order, and modified date.

**Figure 4-4. Newly Added Project Files Display a ‘?’ for Status**

![Image showing newly added project files with question marks]

**Changing Compile Order (VHDL)**

By default ModelSim performs default binding of VHDL designs when you load the design with **vsim**. However, you can elect to perform default binding at compile time. (For details, refer to the section **Default Binding** in the User’s Manual.) If you elect to do default binding at compile, then the compile order is important. Follow these steps to change compilation order within a project.

1. Change the compile order.
   a. Select **Compile > Compile Order**.
   
   This opens the Compile Order dialog box.
   
   b. Click the **Auto Generate** button.

ModelSim determines the compile order by making multiple passes over the files. It starts compiling from the top; if a file fails to compile due to dependencies, it moves that file to the bottom and then recompiles it after compiling the rest of the files. It continues in this manner until all files compile successfully or until a file(s) can’t be compiled for reasons other than dependency.

Alternatively, you can select a file and use the Move Up and Move Down buttons to put the files in the correct order (Figure 4-5).
c. Click OK to close the Compile Order dialog.

Compile the Design

1. Compile the files.
   a. Right-click either counter.v or tcountr.v in the Project window and select Compile > Compile All from the pop-up menu.

   ModelSim compiles both files and changes the symbol in the Status column to a green check mark. A check mark means the compile succeeded. If compile fails, the symbol will be a red ‘X’, and you will see an error message in the Transcript window.

2. View the design units.
   a. Click the Library tab (Figure 4-6).

   b. Click the ‘+’ icon next to the work library.

      You should see two compiled design units, their types (modules in this case), and the path to the underlying source files.
Projects
Create a New Project

Figure 4-6. Library Window with Expanded Library

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>work</td>
<td>Library</td>
<td>C:/tutorials/verilog/projects/work</td>
</tr>
<tr>
<td>counter</td>
<td>Module</td>
<td>C:/tutorials/verilog/projects/counter.v</td>
</tr>
<tr>
<td>test_counter</td>
<td>Module</td>
<td>C:/tutorials/verilog/projects/tcounter.v</td>
</tr>
<tr>
<td>floatfixlib</td>
<td>Library</td>
<td>$MODEL_TECH/floatfixlib</td>
</tr>
<tr>
<td>mtAvm</td>
<td>Library</td>
<td>$MODEL_TECH/avm</td>
</tr>
<tr>
<td>mtOvm</td>
<td>Library</td>
<td>$MODEL_TECH/ovm-2.0</td>
</tr>
<tr>
<td>mtULPF</td>
<td>Library</td>
<td>$MODEL_TECH/uulp_f</td>
</tr>
<tr>
<td>sv_std</td>
<td>Library</td>
<td>$MODEL_TECH/sv_std</td>
</tr>
<tr>
<td>vital2000</td>
<td>Library</td>
<td>$MODEL_TECH/vital2000</td>
</tr>
<tr>
<td>ieee</td>
<td>Library</td>
<td>$MODEL_TECH/ieee</td>
</tr>
<tr>
<td>modelsim_lib</td>
<td>Library</td>
<td>$MODEL_TECH/modelsim_lib</td>
</tr>
</tbody>
</table>

Load the Design

1. Load the test_counter design unit.
   a. Double-click the test_counter design unit.

   The Structure (sim) window appears as part of the tab group with the Library and Project windows (Figure 4-7).

Figure 4-7. Structure(sim) window for a Loaded Design

At this point you would typically run the simulation and analyze or debug your design like you did in the previous lesson. For now, you’ll continue working with
the project. However, first you need to end the simulation that started when you loaded `test_counter`.

2. End the simulation.
   a. Select **Simulate > End Simulation**.
   b. Click **Yes**.

**Organizing Projects with Folders**

If you have a lot of files to add to a project, you may want to organize them in folders. You can create folders either before or after adding your files. If you create a folder before adding files, you can specify in which folder you want a file placed at the time you add the file (see Folder field in **Figure 4-3**). If you create a folder after adding files, you edit the file properties to move it to that folder.

**Add Folders**

As shown previously in **Figure 4-2**, the Add items to the Project dialog has an option for adding folders. If you have already closed that dialog, you can use a menu command to add a folder.

1. Add a new folder.
   a. Right-click in the Projects window and select **Add to Project > Folder**.
   b. Type **Design Files** in the **Folder Name** field (**Figure 4-8**).
   c. Click **OK**.

The new Design Files folder is displayed in the Project window (**Figure 4-9**).
2. Add a sub-folder.
   a. Right-click anywhere in the Project window and select **Add to Project > Folder**.
   b. Type **HDL** in the **Folder Name** field (Figure 4-10).
   c. Click the **Folder Location** drop-down arrow and select **Design Files**.
   d. Click **OK**.

   A ‘+’ icon appears next to the **Design Files** folder in the Project window (Figure 4-11).
e. Click the ’+’ icon to see the HDL sub-folder.

Moving Files to Folders

If you don’t place files into a folder when you first add the files to the project, you can move them into a folder using the properties dialog.

1. Move tcounter.v and counter.v to the HDL folder.
   a. Select both counter.v and tcounter.v in the Project window.
   b. Right-click either file and select Properties.

   This opens the Project Compiler Settings dialog (Figure 4-12), which allows you to set a variety of options on your design files.

   ![Figure 4-12. Changing File Location via the Project Compiler Settings Dialog](image)

   c. Click the Place In Folder drop-down arrow and select HDL.
   d. Click OK.

   The selected files are moved into the HDL folder. Click the ’+’ icon next to the HDL folder to see the files.

   The files are now marked with a ’?’ in the Status column because you moved the files. The project no longer knows if the previous compilation is still valid.

Simulation Configurations

A Simulation Configuration associates a design unit(s) and its simulation options. For example, let’s say that every time you load tcounter.v you want to set the simulator resolution to picoseconds (ps) and enable event order hazard checking. Ordinarily, you would have to specify those options each time you load the design. With a Simulation Configuration, you specify options for a design and then save a “configuration” that associates the design and its options.
Projects
Simulation Configurations

The configuration is then listed in the Project window and you can double-click it to load `tcounter.v` along with its options.

1. Create a new Simulation Configuration.
   a. Right-click in the Project window and select **Add to Project > Simulation Configuration** from the popup menu.

   This opens the Add Simulation Configuration dialog (Figure 4-13). The tabs in this dialog present several simulation options. You may want to explore the tabs to see what is available. You can consult the ModelSim User’s Manual to get a description of each option.

   **Figure 4-13. Simulation Configuration Dialog**

   ![Simulation Configuration Dialog](image)

   b. Type `counter` in the **Simulation Configuration Name** field.
   c. Select `HDL` from the **Place in Folder** drop-down.
   d. Click the ‘+’ icon next to the `work` library and select `test_counter`.

...
e. Click the **Resolution** drop-down and select *ps*.

f. For Verilog, click the Verilog tab and check **Enable hazard checking (-hazards)**.

g. Click **Save**.

The files *tcounter.v* and *counter.v* show question mark icons in the status column because they have changed location since they were last compiled and need to be recompiled.

h. Select one of the files, *tcounter.v* or *counter.v*.

i. Select **Compile > Compile All**.

The Project window now shows a Simulation Configuration named *counter* in the HDL folder (Figure 4-14).

**Figure 4-14. A Simulation Configuration in the Project window**

2. Load the Simulation Configuration.

   a. Double-click the *counter* Simulation Configuration in the Project window.

   In the Transcript window of the Main window, the *vsim* (the ModelSim simulator) invocation shows the **-hazards** and **-t ps** switches (Figure 4-15). These are the command-line equivalents of the options you specified in the Simulate dialog.

**Figure 4-15. Transcript Shows Options for Simulation Configurations**
Lesson Wrap-Up

This concludes this lesson. Before continuing you need to end the current simulation and close the current project.

1. Select Simulate > End Simulation. Click Yes.
2. In the Project window, right-click and select Close Project.

   If you do not close the project, it will open automatically the next time you start ModelSim.
Chapter 5
Working With Multiple Libraries

Introduction

In this lesson you will practice working with multiple libraries. You might have multiple libraries to organize your design, to access IP from a third-party source, or to share common parts between simulations.

You will start the lesson by creating a resource library that contains the counter design unit. Next, you will create a project and compile the test bench into it. Finally, you will link to the library containing the counter and then run the simulation.

Design Files for this Lesson

The sample design for this lesson is a simple 8-bit, binary up-counter with an associated test bench. The pathnames are as follows:

Verilog – <install_dir>/examples/tutorials/verilog/libraries/counter.v and tcounter.v

VHDL – <install_dir>/examples/tutorials/vhdl/libraries/counter.vhd and tcounter.vhd

This lesson uses the Verilog files tcounter.v and counter.v in the examples. If you have a VHDL license, use tcounter.vhd and counter.vhd instead.

Related Reading


Creating the Resource Library

Before creating the resource library, make sure the modelsim.ini in your install directory is “Read Only.” This will prevent permanent mapping of resource libraries to the master modelsim.ini file. See Permanently Mapping VHDL Resource Libraries.

1. Create a directory for the resource library.

   Create a new directory called resource_library. Copy counter.v from <install_dir>/examples/tutorials/verilog/libraries to the new directory.

2. Create a directory for the test bench.
Create a new directory called `testbench` that will hold the test bench and project files. Copy `tcounter.v` from `<install_dir>/examples/tutorials/verilog/libraries` to the new directory.

You are creating two directories in this lesson to mimic the situation where you receive a resource library from a third-party. As noted earlier, we will link to the resource library in the first directory later in the lesson.

3. Start ModelSim and change to the `resource_library` directory.

   If you just finished the previous lesson, ModelSim should already be running. If not, start ModelSim.
   
   a. Type `vsim` at a UNIX shell prompt or use the ModelSim icon in Windows.
      
      If the Welcome to ModelSim dialog appears, click `Close`.
   
   b. Select `File > Change Directory` and change to the `resource_library` directory you created in step 1.

4. Create the resource library.

   a. Select `File > New > Library`.
   
   b. Type `parts_lib` in the Library Name field (Figure 5-1).

   ![Figure 5-1. Creating New Resource Library](image)

   The Library Physical Name field is filled out automatically.

   Once you click OK, ModelSim creates a directory for the library, lists it in the Library window, and modifies the `modelsim.ini` file to record this new library for the future.

5. Compile the counter into the resource library.
Working With Multiple Libraries

Creating the Project

1. Create the project.
   a. Select File > New > Project.
   b. Type counter in the Project Name field.
   c. Do not change the Project Location field or the Default Library Name field. (The default library name is work.)

6. Change to the testbench directory.
   a. Select File > Change Directory and change to the testbench directory you created in step 2.

You now have a resource library containing a compiled version of the counter design unit.

Creating the Project

Now you will create a project that contains testcounter.v, the counter’s test bench.

1. Create the project.
   a. Select File > New > Project.
   b. Type counter in the Project Name field.
   c. Do not change the Project Location field or the Default Library Name field. (The default library name is work.)
d. Make sure “Copy Library Mappings” is selected. The default `modelsim.ini` file will be used.

e. Click OK.

2. Add the test bench to the project.

a. Click **Add Existing File** in the Add items to the Project dialog.

b. Click the **Browse** button and select `tcounter.v` in the “Select files to add to project” dialog.

c. Click **Open**.

d. Click **OK**.

e. Click **Close** to dismiss the “Add items to the Project” dialog.

The `tcounter.v` file is listed in the Project window.

3. Compile the test bench.

a. Right-click `tcounter.v` and select **Compile > Compile Selected**.

---

**Linking to the Resource Library**

To wrap up this part of the lesson, you will link to the `parts_lib` library you created earlier. But first, try loading the test bench without the link and see what happens.

ModelSim responds differently for Verilog and VHDL in this situation.

**Verilog**

**Load the Verilog Test Bench**

1. Load a Verilog design with a missing resource library.

   a. In the Library window, click the `'+` icon next to the `work` library and double-click `test_counter`.

   The Transcript reports an error (**Figure 5-3**). When you see a message that contains text like "Error: (vsim-3033)", you can view more detail by using the **verror** command.
Working With Multiple Libraries
Linking to the Resource Library

Figure 5-3. Verilog Simulation Error Reported in Transcript

<table>
<thead>
<tr>
<th>Transcript</th>
</tr>
</thead>
</table>
| ModelSim> vsim work.test-counter
| # Loading work.test-counter
| # **Error: (vsim-3033) C:/tutorials/testbench/tcounter.v(15):Instantiation of 'counter' failed. The design unit was not found.
| # Region: /test_counter
| # Searched libraries:
| # C:/tutorials/testbench/work
| # Error loading design
| ModelSim> |
| Project: counter <No Design Loaded> |

b. Type **verror 3033** at the ModelSim> prompt.

The expanded error message tells you that a design unit could not be found for instantiation. It also tells you that the original error message should list which libraries ModelSim searched. In this case, the original message says ModelSim searched only *work*.

c. Type **quit -sim** to quit the simulation.

The process for linking to a resource library differs between Verilog and VHDL. If you are using Verilog, follow the steps in **Linking to a Resource Library**. If you are using VHDL, follow the steps in **Permanently Mapping VHDL Resource Libraries** one page later.

**VHDL**

Load the VHDL Test Bench

1. Load the VHDL test bench with a missing resource library.

a. In the Library window, click the '+' icon next to the *work* library and double-click *test_counter*.

The Main window Transcript reports a warning (Figure 5-4). When you see a message that contains text like "Warning: (vsim-3473)", you can view more detail by using the **verror** command.
Working With Multiple Libraries

Linking to the Resource Library

Figure 5-4. VHDL Simulation Warning Reported in Main Window

<table>
<thead>
<tr>
<th>Transcript</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuestaSim&gt; vsim -voptargs=&quot;+acc&quot; test_counter</td>
</tr>
<tr>
<td># vsim -voptargs=&quot;+acc&quot; test_counter</td>
</tr>
<tr>
<td># **Note: (vsim-3812) Design is being optimized...</td>
</tr>
<tr>
<td># Loading std.standard</td>
</tr>
<tr>
<td># Loading work.test_counter(only)#1</td>
</tr>
<tr>
<td># **Warning: (vsim-3473) Component instance &quot;dut : counter&quot; is not bound.</td>
</tr>
<tr>
<td># Time: 0 ns Iteration: 0 Region: /test_counter File: C:/tutorials/testbench/tcounter.vhd</td>
</tr>
<tr>
<td>VSIM 7&gt;</td>
</tr>
<tr>
<td>Project: counter</td>
</tr>
</tbody>
</table>

b. Type `verror 3473` at the VSIM> prompt.

The expanded error message tells you that a component (’dut’ in this case) has not been explicitly bound and no default binding can be found.

c. Type `quit -sim` to quit the simulation.

Linking to a Resource Library

Linking to a resource library requires that you specify a "search library" when you invoke the simulator.

1. Specify a search library during simulation.
   a. Click the Simulate icon on the Main window toolbar.
   b. Click the ’+’ icon next to the `work` library and select `test_counter`.
   c. Click the Libraries tab.
   d. Click the Add button next to the Search Libraries field and browse to `parts_lib` in the `resource_library` directory you created earlier in the lesson.
   e. Click OK.

The dialog should have `parts_lib` listed in the Search Libraries field (Figure 5-5).

f. Click OK.

The design loads without errors.
Permanently Mapping VHDL Resource Libraries

If you reference particular VHDL resource libraries in every VHDL project or simulation, you may want to permanently map the libraries. Doing this requires that you edit the master `modelsim.ini` file in the installation directory. Though you won’t actually practice it in this tutorial, here are the steps for editing the file:

1. Locate the `modelsim.ini` file in the ModelSim installation directory (`<install_dir>/modeltech/modelsim.ini`).
2. IMPORTANT - Make a backup copy of the file.
3. Change the file attributes of `modelsim.ini` so it is no longer "read-only."
4. Open the file and enter your library mappings in the [Library] section. For example:
   
   \[
   \text{parts\_lib} = \text{C:/libraries/parts\_lib}
   \]
5. Save the file.
6. Change the file attributes so the file is "read-only" again.

---

**Figure 5-5. Specifying a Search Library in the Simulate Dialog**

![Screenshot of specifying a search library in the Simulate dialog.](image)
Lesson Wrap-Up

This concludes this lesson. Before continuing we need to end the current simulation and close the project.

1. Select **Simulate > End Simulation**. Click Yes.
2. Select the Project window to make it active.
3. Select **File > Close**. Click **OK**.
Introduction

The Wave window allows you to view the results of your simulation as HDL waveforms and their values. The Wave window is divided into a number of panes (Figure 6-1). You can resize the pathnames pane, the values pane, and the waveform pane by clicking and dragging the bar between any two panes.

Figure 6-1. Panes of the Wave Window

Related Reading

User’s Manual sections: Wave Window and Recording Simulation Results With Datasets
Loading a Design

For the examples in this lesson, we will use the design simulated in Basic Simulation.

1. If you just finished the previous lesson, ModelSim should already be running. If not, start ModelSim.
   a. Type `vsim` at a UNIX shell prompt or use the ModelSim icon in Windows.
      If the Welcome to ModelSim dialog appears, click Close.

2. Load the design.
   a. Select `File > Change Directory` and open the directory you created in the “Basic Simulation” lesson.
      The `work` library should already exist.
   b. Click the `+` icon next to the `work` library and double-click `test_counter`.
      ModelSim loads the design and opens a Structure (sim) window.

Add Objects to the Wave Window

ModelSim offers several methods for adding objects to the Wave window. In this exercise, you will try different methods.

1. Add objects from the Objects window.
   a. Open an Objects window by selecting `View > Objects`.
   b. Select an item in the Objects window, right-click, and then select `Add > To Wave > Signals in Region`.
      ModelSim opens a Wave window and displays signals in the region.
   c. Place the cursor over an object and click the middle mouse button to place an object in the Wave window.
   d. Select a group of objects then click the middle mouse button while the cursor is placed over the group.

2. Undock the Wave window.

   By default ModelSim opens the Wave window in the right side of the Main window. You can change the default via the Preferences dialog (`Tools > Edit Preferences`). Refer to the Simulator GUI Preferences section in the User’s Manual for more information.
   a. Click the undock icon on the Wave window.
The Wave window becomes a standalone, un-docked window. Resize the window as needed.


You can drag an object to the Wave window from many other windows (e.g., Structure, Objects, and Locals).

a. In the Wave window, select **Edit > Select All** and then **Edit > Delete**.

b. Drag an instance from the Structure (sim) window to the Wave window.

   ModelSim adds the objects for that instance to the Wave window.

c. Drag a signal from the Objects window to the Wave window.

d. In the Wave window, select **Edit > Select All** and then **Edit > Delete**.

4. Add objects using the `add wave` command.

a. Type the following at the VSIM> prompt.

   ```
   add wave *
   ```

   ModelSim adds all objects from the current region.

b. Run the simulation for 500 ns so you can see waveforms.

---

### Zooming the Waveform Display

There are numerous methods for zooming the Waveform display.

1. Zoom the display using various techniques.

   a. Click the Zoom Mode icon on the Wave window toolbar.

   b. In the waveform display, click and drag down and to the right.

   You should see blue vertical lines and numbers defining an area to zoom in (Figure 6-2).
c. Select **View > Zoom > Zoom Last**.
   
The waveform display restores the previous display range.

d. Click the Zoom In icon a few times.

e. In the waveform display, click and drag up and to the right.
   
   You should see a blue line and numbers defining an area to zoom out.

f. Select **View > Zoom > Zoom Full**.

**Using Cursors in the Wave Window**

Cursors mark simulation time in the Wave window. When ModelSim first draws the Wave window, it places one cursor at time zero. Clicking anywhere in the waveform display brings that cursor to the mouse location.

You can also:

- add additional cursors;
- name, lock, and delete cursors;
- use cursors to measure time intervals; and
- use cursors to find transitions.

First, dock the Wave window in the Main window by clicking the dock icon.

**Working with a Single Cursor**

1. Position the cursor by clicking and dragging.
a. Click the Select Mode icon on the Wave window toolbar.

b. Click anywhere in the waveform pane.

A cursor is inserted at the time where you clicked (Figure 6-3).

**Figure 6-3. Working with a Single Cursor in the Wave Window**

![Wave Window with Cursor](image)

c. Drag the cursor and observe the value pane.

The signal values change as you move the cursor. This is perhaps the easiest way to examine the value of a signal at a particular time.

d. In the waveform pane, drag the cursor to the right of a transition with the mouse positioned over a waveform.

The cursor "snaps" to the nearest transition to the left. Cursors "snap" to a waveform edge if you click or drag a cursor to within ten pixels of a waveform edge. You can set the snap distance in the Window Preferences dialog (select **Tools > Window Preferences**).

e. In the cursor pane, drag the cursor to the right of a transition (Figure 6-3).

The cursor doesn’t snap to a transition if you drag in the cursor pane.

2. Rename the cursor.

a. Right-click "Cursor 1" in the cursor pane, and select and delete the text.

b. Type A and press Enter.

The cursor name changes to "A" (Figure 6-4).
Analyzing Waveforms

Using Cursors in the Wave Window

Figure 6-4. Renaming a Cursor

3. Jump the cursor to the next or previous transition.
   a. Click signal count in the pathname pane.
   b. Click the Find Next Transition icon on the Wave window toolbar. The cursor jumps to the next transition on the selected signal.
   c. Click the Find Previous Transition icon on the Wave window toolbar. The cursor jumps to the previous transition on the selected signal.

Working with Multiple Cursors

1. Add a second cursor.
   a. Click the Insert Cursor icon on the Wave window toolbar.
   b. Right-click the name of the new cursor and delete the text.
   c. Type B and press Enter.
   d. Drag cursor B and watch the interval measurement change dynamically (Figure 6-5).

Figure 6-5. Interval Measurement Between Two Cursors
2. Lock cursor B.
   a. Right-click the yellow box associated with cursor B (at 56 ns).
   b. Select **Lock B** from the popup menu.

   The cursor color changes to red and you can no longer drag the cursor (Figure 6-6).

   **Figure 6-6. A Locked Cursor in the Wave Window**

3. Delete cursor B.
   a. Right-click cursor B (the red box at 56 ns) and select **Delete B**.

**Lesson Wrap-Up**

This concludes this lesson. Before continuing we need to end the current simulation.

1. Select **Simulate > End Simulation**. Click Yes.
Chapter 7
Viewing And Initializing Memories

Introduction

In this lesson you will learn how to view and initialize memories. ModelSim defines and lists any of the following as memories:

- reg, wire, and std_logic arrays
- Integer arrays
- Single dimensional arrays of VHDL enumerated types other than std_logic

Design Files for this Lesson

The installation comes with Verilog and VHDL versions of the example design located in the following directories:

**Verilog** – `<install_dir>/examples/tutorials/verilog/memory`

**VHDL** – `<install_dir>/examples/tutorials/vhdl/memory`

This lesson uses the Verilog version for the exercises. If you have a VHDL license, use the VHDL version instead.

Related Reading


Compile and Load the Design

1. Create a new directory and copy the tutorial files into it.
   - Start by creating a new directory for this exercise (in case other users will be working with these lessons). Create the directory and copy all files from `<install_dir>/examples/tutorials/verilog/memory` to the new directory.
   - If you have a VHDL license, copy the files in `<install_dir>/examples/tutorials/vhdl/memory` instead.
2. Start ModelSim and change to the exercise directory.
Viewing And Initializing Memories

View a Memory and its Contents

If you just finished the previous lesson, ModelSim should already be running. If not, start ModelSim.

a. Type `vsim` at a UNIX shell prompt or use the ModelSim icon in Windows.

   If the Welcome to ModelSim dialog appears, click Close.

b. Select File > Change Directory and change to the directory you created in step 1.

3. Create the working library and compile the design.

   a. Type `vlib work` at the ModelSim> prompt.

   b. **Verilog:**  
      Type `vlog *.v` at the ModelSim> prompt to compile all verilog files in the design.

      **VHDL:**  
      Type `vcom -93 sp_syn_ram.vhd dp_syn_ram.vhd ram_tb.vhd` at the ModelSim> prompt.

4. Load the design.

   a. On the Library tab of the Main window Workspace, click the "+" icon next to the `work` library.

   b. Double-click the `ram_tb` design unit to load the design.

View a Memory and its Contents

The Memory window lists all memory instances in the design, showing for each instance the range, depth, and width. Double-clicking an instance opens a window displaying the memory data.

1. Open the Memory window and view the data of a memory instance

   a. If the Memory window is not already open, select View > Memory List.

      A Memory window opens as shown in Figure 7-1.

---

**Figure 7-1. The Memory List in the Memory window**

![Memory List](image.png)
b. Double-click the `/ram_tb/spram1/mem` instance in the memory list to view its contents.

A Memory Data window opens displaying the contents of spram1. The first column (blue hex characters) lists the addresses, and the remaining columns show the data values.

If you are using the Verilog example design, the data is all X (Figure 7-2) because you have not yet simulated the design.

**Figure 7-2. Verilog Memory Data Window**

![Verilog Memory Data Window](image)

If you are using the VHDL example design, the data is all zeros (Figure 7-3).

**Figure 7-3. VHDL Memory Data Window**

![VHDL Memory Data Window](image)

c. Double-click the instance `/ram_tb/spram2/mem` in the Memory window. This opens a second Memory Data window that contains the addresses and data for the spram2 instance. For each memory instance that you click in the Memory window, a new Memory Data window opens.

2. Simulate the design.

   a. Click the run-all icon in the Main window.
Viewing And Initializing Memories

View a Memory and its Contents

A Source window opens showing the source code for the *ram_tb* file at the point where the simulation stopped.

**VHDL:**

In the Transcript window, you will see NUMERIC_STD warnings that can be ignored and an assertion failure that is functioning to stop the simulation. The simulation itself has not failed.

a. Click the **Memory ...spram1/mem** tab to bring that Memory data window to the foreground. The Verilog data fields are shown in **Figure 7-4**.

**Figure 7-4. Verilog Data After Running Simulation**

![Figure 7-4](image-url)

The VHDL data fields are shown in **Figure 7-5**.

**Figure 7-5. VHDL Data After Running Simulation**

![Figure 7-5](image-url)

3. Change the address radix and the number of words per line for instance `/ram_tb/spram1/mem`.

   a. Right-click anywhere in the spram1 Memory Data window and select **Properties**.

   b. The Properties dialog box opens (Figure 7-6).
c. For the **Address Radix**, select **Decimal**. This changes the radix for the addresses only.

d. Select **Words per line** and type 1 in the field.

e. Click OK.

You can see the Verilog results of the settings in **Figure 7-7** and the VHDL results in **Figure 7-8**. If the figure doesn’t match what you have in your ModelSim session, check to make sure you set the Address Radix rather than the Data Radix. Data Radix should still be set to Symbolic, the default.
Navigate Within the Memory

You can navigate to specific memory address locations, or to locations containing particular data patterns. First, you will go to a specific address.

1. Use Goto to find a specific address.
   a. Right-click anywhere in address column and select **Goto** (Figure 7-9).

   The Goto dialog box opens in the data pane.

   **Figure 7-9. Goto Dialog**

   b. Type **30** in the Goto Address field.

   c. Click **OK**.

   The requested address appears in the top line of the window.

2. Edit the address location directly.
   a. To quickly move to a particular address, do the following:
      i. Double click address 38 in the address column.
      ii. Enter address 100 (Figure 7-10).
iii. Press the Enter or Return key on your keyboard.

The pane jumps to address 100.

3. Now, let's find a particular data entry.
   a. Right-click anywhere in the data column and select **Find**.

   The Find in dialog box opens (**Figure 7-11**).

   **Figure 7-11. Searching for a Specific Data Value**

   ![Find dialog box](image)

   b. **Verilog**: Type **1111010** in the **Find data:** field and click **Find Next**.

   **VHDL**: Type **250** in the **Find data:** field and click **Find Next**.

   The data scrolls to the first occurrence of that address. Click **Find Next** a few more times to search through the list.

   c. Click **Close** to close the dialog box.
Export Memory Data to a File

You can save memory data to a file that can be loaded at some later point in simulation.

1. Export a memory pattern from the `/ram_tb/spram1/mem` instance to a file.
   a. Make sure `/ram_tb/spram1/mem` is open and selected.
   b. Select **File > Export > Memory Data** to bring up the Export Memory dialog box (Figure 7-12).

   Figure 7-12. Export Memory Dialog

   - Make sure `/ram_tb/spram1/mem` is open and selected.
   - Select **File > Export > Memory Data** to bring up the Export Memory dialog box (Figure 7-12).

   c. For the Address Radix, select **Decimal**.

   d. For the Data Radix, select **Binary**.

   - Make sure `/ram_tb/spram1/mem` is open and selected.
   - Select **File > Export > Memory Data** to bring up the Export Memory dialog box (Figure 7-12).

   c. For the Address Radix, select **Decimal**.

   d. For the Data Radix, select **Binary**.

   Figure 7-12. Export Memory Dialog

   - Make sure `/ram_tb/spram1/mem` is open and selected.
   - Select **File > Export > Memory Data** to bring up the Export Memory dialog box (Figure 7-12).

   c. For the Address Radix, select **Decimal**.

   d. For the Data Radix, select **Binary**.

   Figure 7-12. Export Memory Dialog

   - Make sure `/ram_tb/spram1/mem` is open and selected.
   - Select **File > Export > Memory Data** to bring up the Export Memory dialog box (Figure 7-12).

   c. For the Address Radix, select **Decimal**.

   d. For the Data Radix, select **Binary**.
e. For the Words per Line, set to 1.
f. Type `data_mem.mem` into the Filename field.
g. Click OK.

You can view the exported file in any editor.

Memory pattern files can be exported as relocatable files, simply by leaving out the address information. Relocatable memory files can be loaded anywhere in a memory because no addresses are specified.

2. Export a relocatable memory pattern file from the `/ram_tb/spram2/mem` instance.
   a. Select the Memory Data window for the `/ram_tb/spram2/mem` instance.
   b. Right-click on the memory contents to open a popup menu and select Properties.
   c. In the Properties dialog, set the Address Radix to Decimal; the Data Radix to Binary; and the Line Wrap to 1 Words per Line. Click OK to accept the changes and close the dialog.
   d. Select File > Export > Memory Data to bring up the Export Memory dialog box.
   e. For the Address Range, specify a Start address of 0 and End address of 250.
   f. For the File Format, select MTI and No addresses to create a memory pattern that you can use to relocate somewhere else in the memory, or in another memory.
   g. For Address Radix select Decimal, and for Data Radix select Binary.
   h. For the Words per Line, set to 1.
   i. Enter the file name as `reloc.mem`, then click OK to save the memory contents and close the dialog. You will use this file for initialization in the next section.

## Initialize a Memory

In ModelSim, it is possible to initialize a memory using one of three methods: from an exported memory file, from a fill pattern, or from both.

First, let’s initialize a memory from a file only. You will use the one you exported previously, `data_mem.mem`.


   This will open a new Memory Data window to display the contents of `/ram_tb/spram3/mem`. Familiarize yourself with the contents so you can identify changes once the initialization is complete.
b. Right-click and select **Properties** to bring up the Properties dialog.

c. Change the Address Radix to **Decimal**, Data Radix to **Binary**, **Words per Line to 1**, and click OK.

2. Initialize *spram3* from a file.

a. Right-click anywhere in the data column and select **Import Data Patterns** to bring up the Import Memory dialog box (Figure 7-13).

**Figure 7-13. Import Memory Dialog**

The default Load Type is File Only.

b. Type *data_mem.mem* in the Filename field.

c. Click **OK**.
The addresses in instance /ram_tb/spram3/mem are updated with the data from data_mem.mem (Figure 7-14).

**Figure 7-14. Initialized Memory from File and Fill Pattern**

In this next step, you will experiment with importing from both a file and a fill pattern. You will initialize spram3 with the 250 addresses of data you exported previously into the relocatable file reloc.mem. You will also initialize 50 additional address entries with a fill pattern.

3. Import the /ram_tb/spram3/mem instance with a relocatable memory pattern (reloc.mem) and a fill pattern.
   a. Right-click in the data column of spram3 and select Import Data Patterns to bring up the Import Memory dialog box.
   b. For Load Type, select Both File and Data.
   c. For Address Range, select Addresses and enter 0 as the Start address and 300 as the End address.

   This means that you will be loading the file from 0 to 300. However, the reloc.mem file contains only 251 addresses of data. Addresses 251 to 300 will be loaded with the fill data you specify next.
   d. For File Load, select the MTI File Format and enter reloc.mem in the Filename field.
   e. For Data Load, select a Fill Type of Increment.
   f. In the Fill Data field, set the seed value of 0 for the incrementing data.
   g. Click OK.
   h. View the data near address 250 by double-clicking on any address in the Address column and entering 250.
Viewing And Initializing Memories

Interactive Debugging Commands

You can see the specified range of addresses overwritten with the new data. Also, you can see the incrementing data beginning at address 251 (Figure 7-15).

Figure 7-15. Data Increments Starting at Address 251

Now, before you leave this section, go ahead and clear the memory instances already being viewed.

4. Right-click in one of the Memory Data windows and select **Close All**.

Interactive Debugging Commands

The Memory Data windows can also be used interactively for a variety of debugging purposes. The features described in this section are useful for this purpose.

1. Open a memory instance and change its display characteristics.
   b. Right-click in the `dpram1` Memory Data window and select **Properties**.
   c. Change the Address and Data Radix to **Hexadecimal**.
   d. Select **Words per line** and enter 2.
   e. Click **OK**. The result should be as in Figure 7-16.
2. Initialize a range of memory addresses from a fill pattern.
   a. Right-click in the data column of `/ram_tb/dpram1/mem` and select Change to open the Change Memory dialog (Figure 7-17).

   **Figure 7-17. Changing Memory Content for a Range of Addresses**

   ![Change Memory dialog](image)

   b. Select Addresses and enter the start address as `0x00000006` and the end address as `0x00000009`. The "0x" hex notation is optional.

   c. Select Random as the Fill Type.

   d. Enter 0 as the Fill Data, setting the seed for the Random pattern.

   e. Click OK.

   The data in the specified range are replaced with a generated random fill pattern (Figure 7-18).
3. Change contents by highlighting.

You can also change data by highlighting them in the Address Data pane.

a. Highlight the data for the addresses 0x0000000c:0x0000000e, as shown in Figure 7-19.

![Figure 7-19. Changing Memory Contents by Highlighting](image)

b. Right-click the highlighted data and select **Change**.

This brings up the Change memory dialog box. Note that the Addresses field is already populated with the range you highlighted.

c. Select **Value** as the Fill Type. (Refer to Figure 7-20)
d. Enter the data values into the Fill Data field as follows: **24 25 26**.
e. Click **OK**.

The data in the address locations change to the values you entered (Figure 7-21).

**Figure 7-21. Changed Memory Contents for the Specified Addresses**

4. **Edit data in place.**

   To edit only one value at a time, do the following:
   a. Double click any value in the Data column.
   b. Enter the desired value and press the Enter or Return key on your keyboard.

     If you needed to cancel the edit function, press the Esc key on your keyboard.
Lesson Wrap-Up

This concludes this lesson. Before continuing we need to end the current simulation.

1. Select **Simulate > End Simulation.** Click Yes.
Chapter 8
Automating Simulation

Introduction

Aside from executing a couple of pre-existing DO files, the previous lessons focused on using ModelSim in interactive mode: executing single commands, one after another, via the GUI menus or Main window command line. In situations where you have repetitive tasks to complete, you can increase your productivity with DO files.

DO files are scripts that allow you to execute many commands at once. The scripts can be as simple as a series of ModelSim commands with associated arguments, or they can be full-blown Tcl programs with variables, conditional execution, and so forth. You can execute DO files from within the GUI or you can run them from the system command prompt without ever invoking the GUI.

Note

This lesson assumes that you have added the `<install_dir>/<platform>` directory to your PATH. If you did not, you will need to specify full paths to the tools (i.e., vlib, vmap, vlog, vcom, and vsim) that are used in the lesson.

Related Reading

User’s Manual Chapter: Tcl and Macros (DO Files).

*Practical Programming in Tcl and Tk*, Brent B. Welch, Copyright 1997

Creating a Simple DO File

Creating a DO file is as simple as typing a set of commands in a text file. In this exercise, you will create a DO file that loads a design, adds signals to the Wave window, provides stimulus to those signals, and then advances the simulation. You can also create a DO file from a saved transcript file. Refer to "Saving a Transcript File as a Macro (DO file)."

1. Change to the directory you created in the "Basic Simulation" lesson.
2. Create a DO file that will add signals to the Wave window, force signals, and run the simulation.
   a. Select **File > New > Source > Do** to create a new DO file.
   b. Enter the following commands into the Source window:
      
      vsim test_counter
Running in Command-Line Mode

add wave count
add wave clk
add wave reset
force -freeze clk 0 0, 1 {50 ns} -r 100
force reset 1
run 100
force reset 0
run 300
force reset 1
run 400
force reset 0
run 200

3. Save the file.
   a. Select File > Save As.
   b. Type sim.do in the File name: field and save it to the current directory.

4. Execute the DO file.
   a. Enter do sim.do at the VSIM> prompt.

   ModelSim loads the design, executes the saved commands and draws the waves in
   the Wave window. (Figure 8-1)

   Figure 8-1. Wave Window After Running the DO File

5. When you are done with this exercise, select File > Quit to quit ModelSim.

Running in Command-Line Mode

We use the term "command-line mode" to refer to simulations that are run from a DOS/ UNIX
prompt without invoking the GUI. Several ModelSim commands (e.g., vsim, vlib, vlog, etc.)
are actually stand-alone executables that can be invoked at the system command prompt.
Additionally, you can create a DO file that contains other ModelSim commands and specify that
file when you invoke the simulator.

1. Create a new directory and copy the tutorial files into it.
Start by creating a new directory for this exercise. Create the directory and copy the following files into it:

- `<install_dir>/examples/tutorials/verilog/automation/counter.v`
- `<install_dir>/examples/tutorials/verilog/automation/stim.do`

This lesson uses the Verilog file `counter.v`. If you have a VHDL license, use the `counter.vhd` and `stim.do` files in the `/<install_dir>/examples/tutorials/vhdl/automation` directory instead.

2. Create a new design library and compile the source file.

   Again, enter these commands at a DOS/ UNIX prompt in the new directory you created in step 1.

   a. Type `vlib work` at the DOS/ UNIX prompt.

   b. For Verilog, type `vlog counter.v` at the DOS/ UNIX prompt. For VHDL, type `vcom counter.vhd`.

3. Create a DO file.

   a. Open a text editor.

   b. Type the following lines into a new file:

   ```
   # list all signals in decimal format
   add list -decimal *

   # read in stimulus
   do stim.do

   # output results
   write list counter.lst

   # quit the simulation
   quit -f
   ```

   c. Save the file with the name `sim.do` and place it in the current directory.

4. Run the batch-mode simulation.

   a. Enter the following command at the DOS/UNIX prompt:

   ```
   vsim -c -do sim.do counter -wlf counter.wlf
   ```

   The `-c` argument instructs ModelSim not to invoke the GUI. The `-wlf` argument saves the simulation results in a WLF file. This allows you to view the simulation results in the GUI for debugging purposes.

5. View the list output.

   a. Open `counter.lst` and view the simulation results. Output produced by the Verilog version of the design should look like the following:
The output may appear slightly different if you used the VHDL version.

6. View the results in the GUI.

Since you saved the simulation results in counter.wlf, you can view them in the GUI by invoking VSIM with the -view argument.

Note
Make sure your PATH environment variable is set with the current version of ModelSim at the front of the string.

a. Type \texttt{vsim -view counter.wlf} at the DOS/UNIX prompt.

The GUI opens and a dataset tab named "counter" is displayed (Figure 8-2).

Figure 8-2. The counter.wlf Dataset in the Main Window Workspace

b. Right-click the \texttt{counter} instance and select \texttt{Add > To Wave > All items in region}.

The waveforms display in the Wave window.

7. When you finish viewing the results, select \texttt{File > Quit} to close ModelSim.
Using Tcl with the Simulator

The DO files used in previous exercises contained only ModelSim commands. However, DO files are really just Tcl scripts. This means you can include a whole variety of Tcl constructs such as procedures, conditional operators, math and trig functions, regular expressions, and so forth.

In this exercise, you create a simple Tcl script that tests for certain values on a signal and then adds bookmarks that zoom the Wave window when that value exists. Bookmarks allow you to save a particular zoom range and scroll position in the Wave window.

1. Create the script.
   a. In a text editor, open a new file and enter the following lines:

      ```tcl
      proc add_wave_zoom {stime num} {
         echo "Bookmarking wave $num"
         bookmark add wave "bk$num" "[expr $stime - 50] [expr $stime + 100]" 0
      }
      ```

      These commands do the following:
      - Create a new procedure called "add_wave_zoom" that has two arguments, stime and num.
      - Create a bookmark with a zoom range from the current simulation time minus 50 time units to the current simulation time plus 100 time units.

      b. Now add these lines to the bottom of the script:

         ```tcl
         add wave -r /*
         when {clk'event and clk="1"} {
            echo "Count is [exa count]"
            if {[examine count]== "00100111"} {
               add_wave_zoom $now 1
            } elseif {[examine count]== "01000111"} {
               add_wave_zoom $now 2
            }
         }
         ```

      These commands do the following:
      - Add all signals to the Wave window.
      - Use a when statement to identify when clk transitions to 1.
      - Examine the value of count at those transitions and add a bookmark if it is a certain value.

   c. Save the script with the name "add_bkmrk.do" into the directory you created in the Basic Simulation lesson.

2. Load the test_counter design unit.
   a. Start ModelSim.
b. Select **File > Change Directory** and change to the directory you saved the DO file to in step 1c above.

c. Enter the following command at the QuestaSim> prompt:

   ```
   vsim test_counter
   ```

3. Execute the DO file and run the design.

   a. Type **do add_bkmrk.do** at the VSIM> prompt.

   b. Type **run 1500 ns** at the VSIM> prompt.

   The simulation runs and the DO file creates two bookmarks.

   c. If the Wave window is docked in the Main window make it the active window (click anywhere in the Wave window), then select **Wave > Bookmarks > bk1**. If the window is undocked, select **View > Bookmarks > bk1** in the Wave window.

   Watch the Wave window zoom in and scroll to the time when *count* is 00100111. Try the *bk2* bookmark as well.

**Lesson Wrap-Up**

This concludes this lesson.

1. Select **File > Quit** to close ModelSim.
Index

— A —
add wave command, 47
al, 53

— B —
break icon, 20
breakpoints
setting, 20
stepping, 23

— C —
customize command-line mode, 70
Compile, 15
compile order, changing, 28
compiling your design, 10
cursors, Wave window, 48

— D —
design library
working type, 11

— E —
error messages, more information, 41
external libraries, linking to, 40

— F —
folders, in projects, 31

— L —
libraries
design library types, 11
linking to external libraries, 40
mapping to permanently, 43
resource libraries, 11
working libraries, 11
working, creating, 13
linking to external libraries, 40

— M —
mapping libraries permanently, 43
memories
changing values, 65
initializing, 61
memory contents, saving to a file, 60

— O —
options, simulation, 33

— P —
projects
adding items to, 26
creating, 25
flow overview, 10
organizing with folders, 31
simulation configurations, 33

— Q —
quit command, 41, 42

— R —
run -all, 20
run command, 19

— S —
saving simulation options, 33
simulation
basic flow overview, 9
restarting, 21
running, 19
simulation configurations, 33
stepping after a breakpoint, 23

— T —
Tcl, using in the simulator, 73
time, measuring in Wave window, 48

— V —
vcom command, 54
verror command, 41
vlib command, 54
vlog command, 54
vsim command, 14
— W —
Wave window
  adding items to, 46
  cursors, 48
  measuring time with cursors, 48
  zooming, 47
working library, creating, 10, 13

— Z —
zooming, Wave window, 47
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4.3. Customer agrees to maintain Beta Code in confidence and shall restrict access to the Beta Code, including the methods and concepts utilized therein, solely to those employees and Customer location(s) authorized by Mentor Graphics to perform beta testing. Customer agrees that any written evaluations and all inventions, product improvements, modifications or developments that Mentor Graphics conceived or made during or subsequent to this Agreement, including those based partly or wholly on Customer’s feedback, will be the exclusive property of Mentor Graphics. Mentor Graphics will have exclusive rights, title and interest in all such property. The provisions of this Subsection 4.3 shall survive termination of this Agreement.

5. RESTRICTIONS ON USE.

5.1. Customer may copy Software only as reasonably necessary to support the authorized use. Each copy must include all notices and legends embedded in Software and affixed to its medium and container as received from Mentor Graphics. All copies shall remain the property of Mentor Graphics or its licensors. Customer shall maintain a record of the number and primary location of all copies of Software, including copies merged with other software, and shall make those records available to Mentor Graphics upon request. Customer shall not make Products available in any form to any person other than Customer’s employees and on-site contractors, excluding Mentor Graphics competitors, whose job performance requires access and who are under obligations of confidentiality. Customer shall take appropriate action to protect the confidentiality of Products and ensure that any person permitted access does not disclose or use it except as permitted by this Agreement. Customer shall give Mentor Graphics written notice of any unauthorized disclosure or use of the Products as soon as Customer learns or becomes aware of such unauthorized disclosure or use. Except as otherwise permitted for purposes of interoperability as specified by applicable and mandatory local law, Customer shall not reverse-assemble, reverse-compile, reverse-engineer or in any way derive any source code from Software. Log files, data files, rule files and script files generated by or for the Software (collectively “Files”), including without limitation files containing Standard Verification Rule Format (“SVRF”) and Tcl Verification Format (“TVF”) which are Mentor Graphics’ proprietary syntaxes for expressing process rules, constitute or include confidential information of Mentor Graphics. Customer may share Files with third parties, excluding Mentor Graphics competitors, provided that the confidentiality of such Files is protected by written agreement at least as well as Customer protects other information of a similar nature or importance, but in any case with at least reasonable care. Customer may use Files containing SVRF or TVF only with Mentor Graphics products. Under no circumstances shall Customer use Software or Files or allow their use for the purpose of developing, enhancing or marketing any product that is in any way competitive with Software, or disclose to any third party the results of, or information pertaining to, any benchmark.

5.2. If any Software or portions thereof are provided in source code form, Customer will use the source code only to correct software errors and enhance or modify the Software for the authorized use. Customer shall not disclose or permit disclosure of source code, in whole or in part, including any of its methods or concepts, to anyone except Customer’s employees or contractors, excluding Mentor Graphics competitors, with a need to know. Customer shall not copy or compile source code in any manner except to support this authorized use.

5.3. Customer may not assign this Agreement or the rights and duties under it, or relocate, sublicense or otherwise transfer the Products, whether by operation of law or otherwise (“Attempted Transfer”), without Mentor Graphics’ prior written consent and payment of Mentor Graphics’ then-current applicable relocation and/or transfer fees. Any Attempted Transfer without Mentor Graphics’ prior written consent shall be a material breach of this Agreement and may, at Mentor Graphics’ option, result in the immediate termination of the Agreement and/or the licenses granted under this Agreement. The terms of this Agreement, including without limitation the licensing and assignment provisions, shall be binding upon Customer’s permitted successors in interest and assigns.
5.4. The provisions of this Section 5 shall survive the termination of this Agreement.

6. SUPPORT SERVICES. To the extent Customer purchases support services, Mentor Graphics will provide Customer updates and technical support for the Products, at the Customer site(s) for which support is purchased, in accordance with Mentor Graphics’ then current End-User Support Terms located at http://supportnet.mentor.com/about/legal/.

7. AUTOMATIC CHECK FOR UPDATES; PRIVACY. Technological measures in Software may communicate with servers of Mentor Graphics or its contractors for the purpose of checking for and notifying the user of updates and to ensure that the Software in use is licensed in compliance with this Agreement. Mentor Graphics will not collect any personally identifiable data in this process and will not disclose any data collected to any third party without the prior written consent of Customer, except to Mentor Graphics’ outside attorneys or as may be required by a court of competent jurisdiction.

8. LIMITED WARRANTY.

8.1. Mentor Graphics warrants that during the warranty period its standard, generally supported Products, when properly installed, will substantially conform to the functional specifications set forth in the applicable user manual. Mentor Graphics does not warrant that Products will meet Customer’s requirements or that operation of Products will be uninterrupted or error free. The warranty period is 90 days starting on the 15th day after delivery or upon installation, whichever first occurs. Customer must notify Mentor Graphics in writing of any nonconformity within the warranty period. For the avoidance of doubt, this warranty applies only to the initial shipment of Software under an Order and does not renew or reset, for example, with the delivery of (a) Software updates or (b) authorization codes or alternate Software under a transaction involving Software re-mix. This warranty shall not be valid if Products have been subject to misuse, unauthorized modification or improper installation. MENTOR GRAPHICS’ ENTIRE LIABILITY AND CUSTOMER’S EXCLUSIVE REMEDY SHALL BE, AT MENTOR GRAPHICS’ OPTION, EITHER (A) REFUND OF THE PRICE PAID UPON RETURN OF THE PRODUCTS TO MENTOR GRAPHICS OR (B) MODIFICATION OR REPLACEMENT OF THE PRODUCTS THAT DO NOT MEET THIS LIMITED WARRANTY. PROVIDED CUSTOMER HAS OTHERWISE COMPLIED WITH THIS AGREEMENT. MENTOR GRAPHICS MAKES NO WARRANTIES WITH RESPECT TO: (A) SERVICES; (B) PRODUCTS PROVIDED AT NO CHARGE; OR (C) BETA CODE; ALL OF WHICH ARE PROVIDED “AS IS.”

8.2. THE WARRANTIES SET FORTH IN THIS SECTION 8 ARE EXCLUSIVE. NEITHER MENTOR GRAPHICS NOR ITS LICENSORS MAKE ANY OTHER WARRANTIES EXPRESS, IMPLIED OR STATUTORY, WITH RESPECT TO PRODUCTS PROVIDED UNDER THIS AGREEMENT. MENTOR GRAPHICS AND ITS LICENSORS SPECIFICALLY DISCLAIM ALL IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NON-INFRINGEMENT OF INTELLECTUAL PROPERTY.

9. LIMITATION OF LIABILITY. EXCEPT WHERE THIS EXCLUSION OR RESTRICTION OF LIABILITY WOULD BE VOID OR INEFFECTIVE UNDER APPLICABLE LAW, IN NO EVENT SHALL MENTOR GRAPHICS OR ITS LICENSORS BE LIABLE FOR INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES (INCLUDING LOST PROFITS OR SAVINGS) WHETHER BASED ON CONTRACT, TORT OR ANY OTHER LEGAL THEORY. EVEN IF MENTOR GRAPHICS OR ITS LICENSORS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN NO EVENT SHALL MENTOR GRAPHICS’ OR ITS LICENSORS’ LIABILITY UNDER THIS AGREEMENT EXCEED THE AMOUNT RECEIVED FROM CUSTOMER FOR THE HARDWARE, SOFTWARE LICENSE OR SERVICE GIVING RISE TO THE CLAIM. IN THE CASE WHERE NO AMOUNT WAS PAID, MENTOR GRAPHICS AND ITS LICENSORS SHALL HAVE NO LIABILITY FOR ANY DAMAGES WHATSOEVER. THE PROVISIONS OF THIS SECTION 9 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

10. HAZARDOUS APPLICATIONS. CUSTOMER ACKNOWLEDGES IT IS SOLELY RESPONSIBLE FOR TESTING ITS PRODUCTS USED IN APPLICATIONS WHERE THE FAILURE OR INACCURACY OF ITS PRODUCTS MIGHT RESULT IN DEATH OR PERSONAL INJURY (“HAZARDOUS APPLICATIONS”). NEITHER MENTOR GRAPHICS NOR ITS LICENSORS SHALL BE LIABLE FOR ANY DAMAGES RESULTING FROM OR IN CONNECTION WITH THE USE OF MENTOR GRAPHICS PRODUCTS IN OR FOR HAZARDOUS APPLICATIONS. THE PROVISIONS OF THIS SECTION 10 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

11. INDEMNIFICATION. CUSTOMER AGREES TO INDEMNIFY AND HOLD HARMLESS MENTOR GRAPHICS AND ITS LICENSORS FROM ANY CLAIMS, LOSS, COST, DAMAGE, EXPENSE OR LIABILITY, INCLUDING ATTORNEYS’ FEES, ARISING OUT OF OR IN CONNECTION WITH THE USE OF PRODUCTS AS DESCRIBED IN SECTION 10. THE PROVISIONS OF THIS SECTION 11 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

12. INFRINGEMENT.

12.1. Mentor Graphics will defend or settle, at its option and expense, any action brought against Customer in the United States, Canada, Japan, or member state of the European Union which alleges that any standard, generally supported Product acquired by Customer hereunder infringes a patent or copyright or misappropriates a trade secret in such jurisdiction. Mentor Graphics will pay costs and damages finally awarded against Customer that are attributable to the action. Customer understands and agrees that as conditions to Mentor Graphics’ obligations under this section Customer must: (a) notify Mentor Graphics promptly in writing of the action; (b) provide Mentor Graphics all reasonable information and assistance to settle or defend the action; and (c) grant Mentor Graphics sole authority and control of the defense or settlement of the action.
12.2. If a claim is made under Subsection 12.1 Mentor Graphics may, at its option and expense, (a) replace or modify the Product so that it becomes noninfringing; (b) procure for Customer the right to continue using the Product; or (c) require the return of the Product and refund to Customer any purchase price or license fee paid, less a reasonable allowance for use.

12.3. Mentor Graphics has no liability to Customer if the action is based upon: (a) the combination of Software or hardware with any product not furnished by Mentor Graphics; (b) the modification of the Product other than by Mentor Graphics; (c) the use of other than a current unaltered release of Software; (d) the use of the Product as part of an infringing process; (e) a product that Customer makes, uses, or sells; (f) any Beta Code or Product provided at no charge; (g) any software provided by Mentor Graphics’ licensors who do not provide such indemnification to Mentor Graphics’ customers; or (h) infringement by Customer that is deemed willful. In the case of (h), Customer shall reimburse Mentor Graphics for its reasonable attorney fees and other costs related to the action.

12.4. THIS SECTION 12 IS SUBJECT TO SECTION 9 ABOVE AND STATES THE ENTIRE LIABILITY OF MENTOR GRAPHICS AND ITS LICENSORS FOR DEFENSE, SETTLEMENT AND DAMAGES, AND CUSTOMER’S SOLE AND EXCLUSIVE REMEDY, WITH RESPECT TO ANY ALLEGED PATENT OR COPYRIGHT INFRINGEMENT OR TRADE SECRET MISAPPROPRIATION BY ANY PRODUCT PROVIDED UNDER THIS AGREEMENT.

13. TERMINATION AND EFFECT OF TERMINATION. If a Software license was provided for limited term use, such license will automatically terminate at the end of the authorized term.

13.1. Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement immediately upon written notice if Customer: (a) exceeds the scope of the license or otherwise fails to comply with the licensing or confidentiality provisions of this Agreement, or (b) becomes insolvent, files a bankruptcy petition, institutes proceedings for liquidation or winding up or enters into an agreement to assign its assets for the benefit of creditors. For any other material breach of any provision of this Agreement, Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement upon 30 days written notice if Customer fails to cure the breach within the 30 day notice period. Termination of this Agreement or any license granted hereunder will not affect Customer’s obligation to pay for Products shipped or licenses granted prior to the termination, which amounts shall be payable immediately upon the date of termination.

13.2. Upon termination of this Agreement, the rights and obligations of the parties shall cease except as expressly set forth in this Agreement. Upon termination, Customer shall ensure that all use of the affected Products ceases, and shall return hardware and either return to Mentor Graphics or destroy Software in Customer’s possession, including all copies and documentation, and certify in writing to Mentor Graphics within ten business days of the termination date that Customer no longer possesses any of the affected Products or copies of Software in any form.

14. EXPORT. The Products provided hereunder are subject to regulation by local laws and United States government agencies, which prohibit export or diversion of certain products and information about the products to certain countries and certain persons. Customer agrees that it will not export Products in any manner without first obtaining all necessary approval from appropriate local and United States government agencies.

15. U.S. GOVERNMENT LICENSE RIGHTS. Software was developed entirely at private expense. All Software is commercial computer software within the meaning of the applicable acquisition regulations. Accordingly, pursuant to US FAR 48 CFR 12.212 and DFAR 48 CFR 227.7202, use, duplication and disclosure of the Software by or for the U.S. Government or a U.S. Government subcontractor is subject solely to the terms and conditions set forth in this Agreement, except for provisions which are contrary to applicable mandatory federal laws.

16. THIRD PARTY BENEFICIARY. Mentor Graphics Corporation, Mentor Graphics (Ireland) Limited, Microsoft Corporation and other licensors may be third party beneficiaries of this Agreement with the right to enforce the obligations set forth herein.

17. REVIEW OF LICENSE USAGE. Customer will monitor the access to and use of Software. With prior written notice and during Customer’s normal business hours, Mentor Graphics may engage an internationally recognized accounting firm to review Customer’s software monitoring system and records deemed relevant by the internationally recognized accounting firm to confirm Customer’s compliance with the terms of this Agreement or U.S. or other local export laws. Such review may include FLEXlm or FLEXnet (or successor product) report log files that Customer shall capture and provide at Mentor Graphics’ request. Customer shall make records available in electronic format and shall fully cooperate with data gathering to support the license review. Mentor Graphics shall bear the expense of any such review unless a material non-compliance is revealed. Mentor Graphics shall treat as confidential information all information gained as a result of any request or review and shall only use or disclose such information as required by law or to enforce its rights under this Agreement. The provisions of this Section 17 shall survive the termination of this Agreement.

18. CONTROLLING LAW, JURISDICTION AND DISPUTE RESOLUTION. The owners of certain Mentor Graphics intellectual property licensed under this Agreement are located in Ireland and the United States. To promote consistency around the world, disputes shall be resolved as follows: excluding conflict of laws rules, this Agreement shall be governed by and construed under the laws of the State of Oregon, USA, if Customer is located in North or South America, and the laws of Ireland if Customer is located outside of North or South America. All disputes arising out of or in relation to this Agreement shall be submitted to the exclusive jurisdiction of the courts of Portland, Oregon when the laws of Oregon apply, or Dublin, Ireland when the laws of Ireland apply. Notwithstanding the foregoing, all disputes in Asia arising out of or in relation to this Agreement shall be resolved by arbitration in Singapore before a single arbitrator to be appointed by the chairman of the Singapore International Arbitration Centre (“SIAC”) to be conducted in the English language, in accordance with the Arbitration Rules of the SIAC in effect at the time of the dispute, which rules are deemed to be incorporated by reference in this section. This section shall not
restrict Mentor Graphics’ right to bring an action against Customer in the jurisdiction where Customer’s place of business is located. The United Nations Convention on Contracts for the International Sale of Goods does not apply to this Agreement.

19. **SEVERABILITY.** If any provision of this Agreement is held by a court of competent jurisdiction to be void, invalid, unenforceable or illegal, such provision shall be severed from this Agreement and the remaining provisions will remain in full force and effect.

20. **MISCELLANEOUS.** This Agreement contains the parties’ entire understanding relating to its subject matter and supersedes all prior or contemporaneous agreements, including but not limited to any purchase order terms and conditions. Some Software may contain code distributed under a third party license agreement that may provide additional rights to Customer. Please see the applicable Software documentation for details. This Agreement may only be modified in writing by authorized representatives of the parties. Waiver of terms or excuse of breach must be in writing and shall not constitute subsequent consent, waiver or excuse.

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