



Center for Embedded Computer Systems  
University of California, Irvine

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# **Embedded System Environment**

**ESE Version 2.0.0**

**User Manual**

**Version 2.0  
September 2008**

# **Embedded System Environment: ESE Version 2.0.0; User Manual**

Version 2.0

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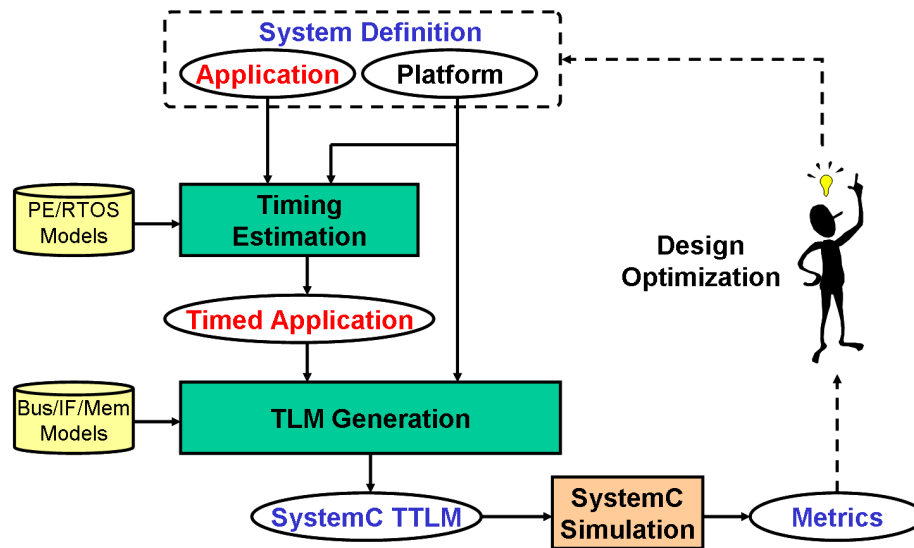
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## Chapter 1. Introduction



**Figure 1-1. Embedded System Environment.**

The Embedded System Environment(ESE) is shown in Figure 1-1. The input to ESE front-end is the system definition consisting of a platform and application code. A library of processing elements, buses, bridges and RTOS is provided in ESE to develop such a platform. The retargetable timing estimation tool in ESE is used to annotate timing to the application code based on the mapping of application code on the platform components. The timed application and platform are input to the Transaction Level Model (TLM) generator tool that uses the bus and bridge models to generate a SystemC TLM. This SystemC TLM can be simulated by any commercial or freely available SystemC simulator to provide the performance metrics. The designer can use the metrics to optimize (i) the application code, (ii) the platform, and/or (iii) the mapping from the application to the platform. Since timing estimation and high-speed TLM generation in ESE are extremely fast, TLMs can be generated and simulated in minutes. This allows fast and early exploration of various design options with ESE.

The ESE provides an environment for modeling, estimation and validation. It includes a graphical user interface (GUI) and a set of tools to facilitate the design flow and perform

the aforementioned optimization steps. The two major components of the GUI are the Design Decision Interface (DDI) and the Validation User Interface (VUI). The DDI allows designers to make and input design decisions, such as allocation of HW and SW components in the platform, and the mapping of application to the platform. With design decisions made, TLM generation and estimation tools can be invoked to generate functional and timed TLMs. The VUI allows the simulation of all TLMs using the OSCI SystemC simulator to validate the design at each stage of the design flow.

With the assistance of the GUI and automatic TLM generation tools, it is relatively easy for designer to step through the design process. With the editing, browsing and algorithm selection capability provided by the GUI, the C application processes can be efficiently captured by designers. Communication channels between the application processes can be created using an intuitive channel wizard. The HW platform can be allocated easily by simple drag-drop of components from the database. The processing elements (PEs), bridges and buses can be connected using ports. The mapping of the processes to PEs and channels to buses/routes can also be done easily in the GUI. The TLM generation tools can be used to verify both the functional correctness of the design and to accurately estimate the performance. Various statistics are generated automatically by the tied TLM simulation. These statistics can be viewed graphically using the GUI.



## Chapter 2. Usage

In the following sections, the general usage of the ESE application will be outlined. Followed by a description of basic formatting conventions used throughout the manual, information pertinent to running the ESE application will be provided.

### 2.1. Manual Conventions

The following style and formatting conventions are used throughout the text of this manual to refer to commands, actions, or GUI elements:

#### **Command**

Refers to a command or other data input typed in and entered by the user.

#### **Message**

Refers to a log or other text message produced by the ESE application on the screen.

#### **Key**

Refers to a key that a user can press on the keyboard.

#### **Label**

Refers to a button, menu or any other general label in the GUI of the ESE main application.

#### **Win::Sub**

Refers to a sub-item inside one of the parts of the ESE application main window.

Win refers to one of the following parts of the application main window (see Chapter 3 *Main Window* (page 7)):

- **Main** represents the Main Window itself (i.e. its menu or tool bar).
- **Project** represents the Project Window.
- **Output** represents the Output Window.
- **Design** represents the Design Window.

Sub refers to drop-down menus or sub windows (tabs):

- For the Main Window, Sub is either File, View, Project, Synthesis, or Windows (drop-down menus introduced in Section 3.1 *Menu Bar* (page 8)).
- For the Project Window, Sub is either Models, Imports, or Sources (tabs introduced in.
- For the Output Window, Sub is either Compile or Refine (tabs introduced in.
- For the Design Window, Sub is either Hierarchy, Behaviors, or Channels (sidebar tabs introduced.

For example, `Project::Models` refers to the models tab in the Project Window.

### Menu→Command

Refers to a main menu or context menu command (described in) where **Command** refers to the menu command and **Menu** refers to a main menu entry or to a context menu in a named subwindow (tab).

For example, `Main::File→Open...` refers to the `Open...` command in the `File` menu of the Main Window menu bar. On the other hand, `Project::Models→Open` refers to the `Open` command in the context menu of the Project Window Models tab.

## 2.2. Starting ESE

ESE is invoked by entering

```
% ese
```

at the command line prompt (%). This will start the application and open the main window (Chapter 3 *Main Window* (page 7)) of the combined SCE graphical user interface (GUI).

### 2.2.1. Scripting

ESE supports scripting of the complete environment from the command line without the need to invoke the GUI. For scripting purposes, a GUI-less command shell of ESE can

be invoked by entering

**% `scsh`**

at the command line prompt (%). This will start the ESE shell without the GUI layer. Instead, a prompt (>>) is offered to enter commands that allow to drive the ESE environment interactively (or from ESE shell scripts read from files supplied on the **`scsh`** command line).

The ESE shell is based on an embedded Python interpreter. As such, it conforms to Python syntax and the full semantics of the Python language is available. In addition, the ESE shell extends the Python interpreter with an API for access to ESE functionality. However, the ESE shell API only provides undocumented low-level access to ESE internals for developers.

For user-level scripting of ESE by designers, a complete set of high-level scripts on top of the ESE shell are available. The set of scripts provides a convenient command-line interface for all necessary ESE functionality. Together with command-line interfaces to model refinement tools and to the SpecC compiler, complete scripting of the ESE design flow from the command line, through shell scripts or via Makefiles is possible.

## 2.2.2. Environment Variables

### HOME

Determines the location of the user's home directory and consequently the default path to the file with user-specific application preferences (\$HOME/.ese/eserc).

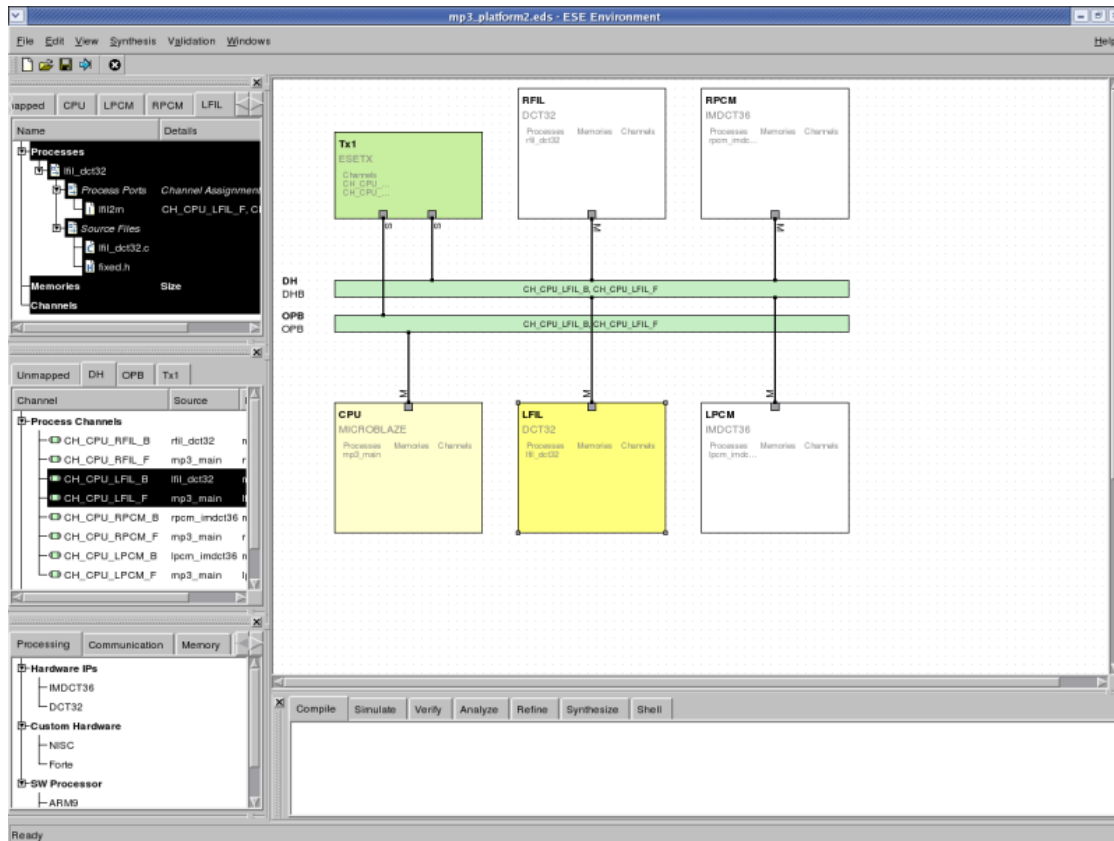
### ESERC\_PATH

Determines the list of directories where files `serrc` with user-specific application preferences are stored. Multiple directories can be provided, separated by colons (":"). Directories are searched for and preference files are read in the given order, i.e. preference files in later directories can override settings in earlier ones. Modified preferences will be written to the first directory in the list that is writeable by the user.

If `ESERC_PATH` is not set, the location (directory) of the user-specific `serrc` file defaults to \$HOME/.ese.



## Chapter 3. Main Window



**Figure 3-1. Main Window of ESE.**

The primary GUI of ESE is the Main Window, which is displayed in Figure 3-1. The Main Window consists of eight parts:

1. A Menu Bar that contains seven columns of commands. Each column is a drop-down menu.
2. A Tool Bar that contains a list of short-cut icons. Each icon represents a command in the menu bar.
3. A PE Window that contains the current design's PE's.
4. A Channel Window that contains the current design's busses and channels.

5. A Database Window that contains the current database's available components.
6. A Design Canvas that contains the graphical representations of the objects of the current design.
7. An Output Window.
8. A Status Bar that displays the current status of ESE, such as `Loading . . .` or `Ready`.

In this section, we introduce organization-related and display-related details of Menu Bar, PE Window, Channel Window, Database Window, Design Canvas, and Output Window. Some windows contain drop-down menus or pop-up menus. The menus further contain design commands. The usage and functionality behind the commands will be described later.

## 3.1. Menu Bar

The Menu Bar contains seven main menu entries: **File**, **Edit**, **View**, **Synthesis**, **Validation**, **Windows**, and **Help**. Each main menu entry is a drop-down menu which contains a number of commands. In general, unless otherwise noted, selecting a main menu entry will apply the corresponding action to the currently active design, i.e. to the design that is currently open. If there is no currently active design, menu commands will silently fail (do nothing).

### 3.1.1. File Menu

The **File** menu contains ten commands:

**File**→**New...**

Selecting **New...** will create a new design file (see Section 4.2.1 *Design Creation* (page 34)).

**File**→**Open...**

Selecting **Open...** will allow loading and opening of an existing design file (see Section 4.2.2 *Design Opening* (page 34)).

**File→Close**

Selecting **Close** will close the current design (see Section 4.2.5 *Design Closing* (page 37)).

**File→Reload**

Selecting **Reload** will trigger reloading of the current design file from disk (e.g. in case the file has changed on disk or reverting to the last saved version) (see Section 4.2.4 *Design Reloading* (page 37)).

**File→Save**

Selecting **Save** will save the current design file (see Section 4.2.3 *Design Saving* (page 36)).

**File→Save As...**

Selecting **Save As...** will save the current design file as a another file (see Section 4.2.3 *Design Saving* (page 36)).

**File→Export...**

Selecting **Export...** will allow saving and exporting of the current design in a compressed file format (see Section 4.2.6 *Design Exporting* (page 38)).

**File→Settings...**

Selecting **Settings...** will display the settings of the current design file (see Section 4.2.7 *Design Settings Editing* (page 39)).

**File→Exit**

Selecting **Exit** will exit from and quit ESE (see Section 4.2.9 *ESE Exiting* (page 41)).

### 3.1.2. Edit Menu

The Edit menu contains one command:

Edit—>Preferences...

Selecting Preferences... will allow viewing and modifying of application preferences (see Section 4.1 *Application Preferences* (page 29)).

### 3.1.3. View Menu

The View menu contains three commands:

View—>Source...

Selecting Source... will allow viewing of the source file of the current design (see Section 4.2.8 *Design Source Viewing* (page 40)).

View—>Chart...

Selecting Chart... will display the chart of the current design.

View—>Connectivity...

Selecting Connectivity... will display the connectivity chart of the current design.

### 3.1.4. Synthesis Menu

The Synthesis menu contains five commands:

Synthesis—>Generate Functional TLM...

Selecting Generate Functional TLM... generates the functional tlm for the current design (see Section 4.4.1 *Generate Functional TLM* (page 64)).

Synthesis—>Generate Timed TLM...

Selecting Generate Timed TLM... generates the timed tlm for the current design (see Section 4.4.2 *Generate TLM* (page 64)).



**Synthesis—>Select Board...**

Selecting **Select Board...** presents a sub-menu, which allows selection of the board to which the current design can be synthesized.

**Synthesis—>Synthesize to Board...**

Selecting **Synthesize to Board...** synthesizes the current design onto the selected board.

**Synthesis—>Stop**

Selecting **Stop** stops any running generation and synthesizing processes for the current design.

### 3.1.5. Validation Menu

The Validation menu contains four commands:

**Validation—>Simulate Functional TLM...**

Selecting **Simulate Functional TLM...** simulates the functional tlm for the current design (see Section 4.5.1 *Simulate Functional TLM* (page 64)).

**Validation—>Simulate Timed TLM...**

Selecting **Simulate Timed TLM...** simulates the timed tlm for the current design (see Section 4.5.2 *Simulate Timed TLM* (page 64)).

**Validation—>Kill Simulation...**

Selecting **Kill Simulation...** presents a sub-menu allowing the selection of which active simulation to terminate from the current design.

**Validation—>View Log...**

Selecting **View Log...** shows the log of the current design.

### **3.1.6. Windows Menu**

The Windows menu contains two commands:

Windows—→Output Window

Selecting **Output Window** will display or undisplay the Output Window (see Section 3.6 *Output Window* (page 25)).

Windows—→Toolbars

Selecting **Toolbars** presents a sub-menu allowing the selection of toolbar(s) to show/hide.

### **3.1.7. Help**

The Help menu contains two commands:

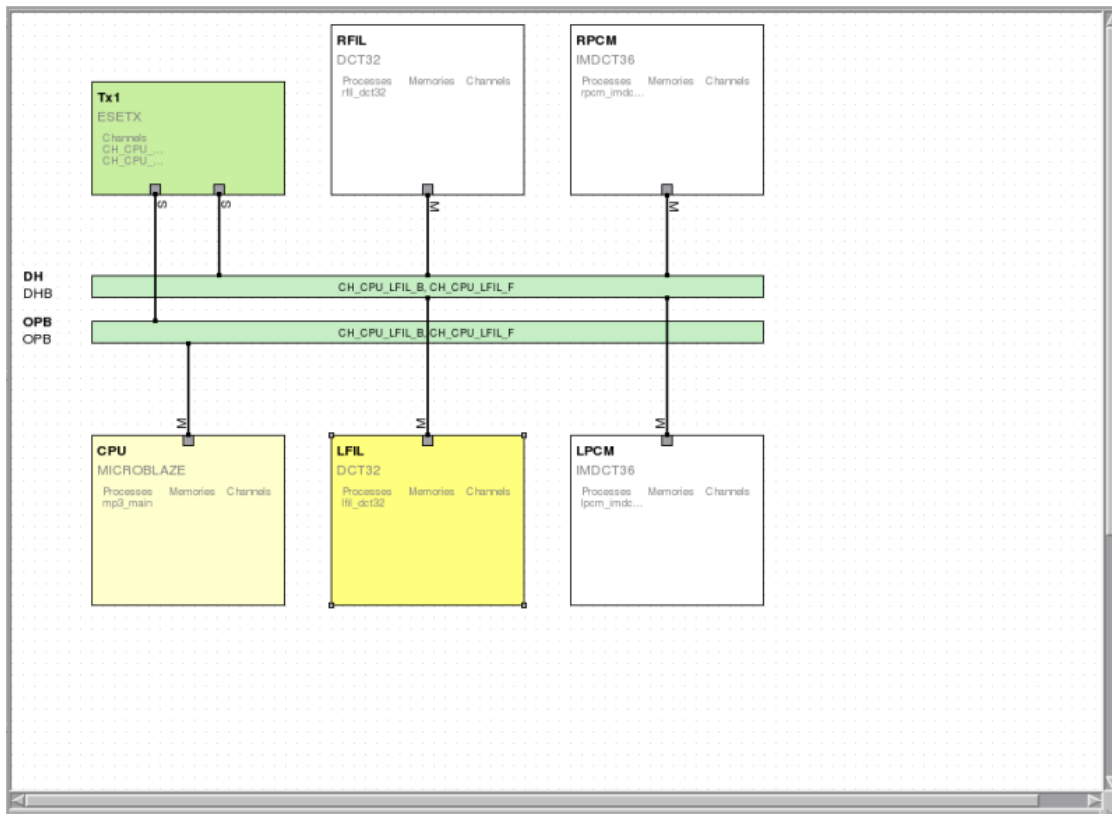
Help—→Manual...

Selecting **Manual...** will open the ESE user manual in the online help browser.

Help—→About...

Selecting **About...** will pop up a dialog with version and copyright information of the ESE environment.

## 3.2. Design Canvas

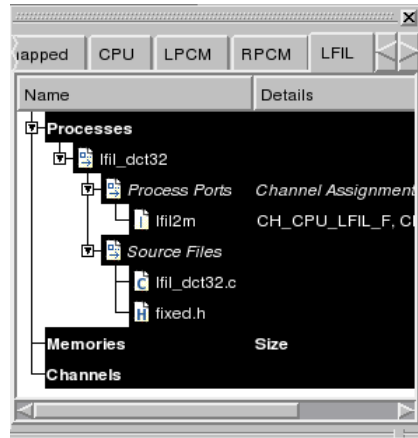


**Figure 3-2. Design Canvas.**

The Design Canvas displays the content and the attributes of an opened design graphically, and it allows browsing and manipulating of the design objects. The Design Canvas is displayed in Figure 3-2.

The canvas supports modifying the layout and attributes of the design via drag-and-drop and through a context menu. Dragging objects from the Database Window adds an object to the design. Dragging objects within the Design Canvas repositions the object accordingly. Deletion, renaming, adding and removing ports, as well as viewing properties are accessed via the context menu and available dependent upon the type of object currently selected (see Section 4.2 *Design Handling* (page 32)).

### 3.3. PE Window



**Figure 3-3. PE Window.**

In the PE Window side bar, all the processes, source files, local memories and local channels associated with each PE in the design are listed. Every PE is represented as a tab in the PE Window. Unmapped processes, local memories, and local channels are displayed in the Unmapped tab. The PE Window is displayed in Figure 3-3.

Each PE tab contains processes, local memories, and local channels. The **Processes** category contains all processes for the PE. If available, each process displays associated **Process Ports** and **Source Files**. **Internal Memories** and **Exposed Memories** are displayed under the **Memories** category. The **Channels** category displays the PE's **Process Channels**, **Memory Channels** and **FIFO Channels**.

#### 3.3.1. PE Window Processes

Right-clicking on the **Processes** category in the PE Window opens a context-menu pop-up for the selected processes. The context menu for **Processes** contains two commands:

##### Add Process

Selecting **Add Process** will add a new instance of the selected entity (see Section 4.3.2 *PE Mapping* (page 44)).

### **Remove All Processes**

Selecting **Remove All Processes** will remove all entities of the selected type (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on a process under the **Processes** category in the PE Window opens a context-menu pop-up for the selected process. The context menu for each process contains eight commands:

### **Rename Process**

Selecting **Rename Process** will rename the selected entity (see Section 4.3.2 *PE Mapping* (page 44)).

### **Add Process**

Selecting **Add Process** will add a new instance of the selected entity (see Section 4.3.2 *PE Mapping* (page 44)).

### **Remove Process(es)**

Selecting **Remove Process(es)** will remove all entities of the selected type (see Section 4.3.2 *PE Mapping* (page 44)).

### **Add .C File(s)**

Selecting **Add .C File(s)** will add a new source file of the specified type (see Section 4.3.2 *PE Mapping* (page 44)).

### **Add .H File(s)**

Selecting **Add .H File(s)** will add a new source file of the specified type (see Section 4.3.2 *PE Mapping* (page 44)).

### **Remove All Source File(s)**

Selecting **Remove All Source File(s)** will remove all entities of the selected type from the process (see Section 4.3.2 *PE Mapping* (page 44)).

### **Add Process Port**

Selecting **Add Process Port** will add a new instance of the selected entity to the process (see Section 4.3.2 *PE Mapping* (page 44)).

### **Remove All Process Port(s)**

Selecting **Remove All Process Port(s)** will remove all entities of the selected type from the process (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on **Process Ports** under a Process in the PE Window opens a context-menu pop-up for the selected process ports. The context menu for **Process Ports** contains two commands:

### **Add Process Port**

Selecting **Add Process Port** will add a new instance of the selected entity to the process (see Section 4.3.2 *PE Mapping* (page 44)).

### **Remove All Process Port(s)**

Selecting **Remove All Process Port(s)** will remove all entities of the selected type from the process (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on a process port under **Process Ports** in the PE Window opens a context-menu pop-up for the selected process class. The context menu for each process port contains three commands:

### **Add Process Port**

Selecting **Add Process Port** will add a new instance of the selected entity to the process (see Section 4.3.2 *PE Mapping* (page 44)).

### **Remove Process Port(s)**

Selecting **Remove Process Port(s)** will remove the selected entities of the selected type from the process (see Section 4.3.2 *PE Mapping* (page 44)).

### **Properties**

Selecting **Properties** will open a properties dialog box the selected entity from the process. The user is able to rename the function names for the entity in this dialog box (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on **Source Files** under a process in the PE Window opens a context-menu pop-up for the selected source files. The context menu for **Source Files** contains three commands:

**Add .C File(s)**

Selecting **Add .C File(s)** will add a new source file of the specified type (see Section 4.3.2 *PE Mapping* (page 44)).

**Add .H File(s)**

Selecting **Add .H File(s)** will add a new source file of the specified type (see Section 4.3.2 *PE Mapping* (page 44)).

**Remove All Source File(s)**

Selecting **Remove All Source File(s)** will remove all entities of the selected type from the process (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on a source file under **Source Files** in the PE Window opens a context-menu pop-up for the selected source files. The context menu for each source file contains four commands:

**Add .C File(s)**

Selecting **Add .C File(s)** will add a new source file of the specified type (see Section 4.3.2 *PE Mapping* (page 44)).

**Add .H File(s)**

Selecting **Add .H File(s)** will add a new source file of the specified type (see Section 4.3.2 *PE Mapping* (page 44)).

**Remove File(s)**

Selecting **Remove File(s)** will remove all selected entities of the selected type from the process (see Section 4.3.2 *PE Mapping* (page 44)).

**View Source**

Selecting **View Source** will open the **Design Viewer** and show the source code for the file (see Section 4.3.2 *PE Mapping* (page 44)).

### **3.3.2. PE Window Memories**

Right-clicking on the **Memories** category in the PE Window opens a context-menu pop-up for the selected process class. The context menu for **Memories** contains three commands:

### Add Exposed Memory

Selecting Add Exposed Memory will add a new instance of the selected entity (see Section 4.3.2 *PE Mapping* (page 44)).

### Add Internal Memory

Selecting Add Internal Memory will add a new instance of the selected entity (see Section 4.3.2 *PE Mapping* (page 44)).

### Remove All Selected Memories

Selecting Remove All Selected Memories will remove all entities of the selected type (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on the **Exposed** sub-category under the **Memories** category in the PE Window opens a context-menu pop-up for the selected process class. The context menu for **Exposed** contains two commands:

### Add Exposed Memory

Selecting Add Exposed Memory will add a new instance of the selected entity (see Section 4.3.2 *PE Mapping* (page 44)).

### Remove All Exposed Memories

Selecting Remove All Exposed Memories will remove all entities of the selected type (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on a memory under the **Exposed** sub-category in the PE Window opens a context-menu pop-up for the selected process class. The context menu for **Exposed** contains four commands:

### Rename Memory

Selecting Rename Memory will allow the user to rename the selected entity (see Section 4.3.2 *PE Mapping* (page 44)).

### Add Exposed Memory

Selecting Add Exposed Memory will add a new instance of the selected entity (see Section 4.3.2 *PE Mapping* (page 44)).



### Remove Selected Memories

Selecting **Remove Selected Memories** will remove selected entities of the selected type from the process (see Section 4.3.2 *PE Mapping* (page 44)).

### Set Memory Size

Selecting **Set Memory Size** will allow the user to set the size of the entity under the **Details** column (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on the **Internal** sub-category under the **Memories** category in the PE Window opens a context-menu pop-up for the selected process class. The context menu for **Internal** contains two commands:

### Add Internal Memory

Selecting **Add Internal Memory** will add a new instance of the selected entity (see Section 4.3.2 *PE Mapping* (page 44)).

### Remove All Internal Memories

Selecting **Remove All Internal Memories** will remove all entities of the selected type (see Section 4.3.2 *PE Mapping* (page 44)).

## 3.3.3. PE Window Channels

Right-clicking on the **Channels** category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for **Channels** contains one command:

### Remove Selected Channels

Selecting **Remove Selected Channels** will remove all entities of the selected type (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on the **Process Channels** sub-category under the **Channels** category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for **Process Channels** contains one command:

### Remove Selected Channels

Selecting **Remove Selected Channels** will remove all entities of the selected type (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on a channel under the **Process Channels** sub-category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for **Process Channels** contains two commands:

#### **Remove Channel(s)**

Selecting **Remove Channel(s)** will remove all selected entities of type (see Section 4.3.2 *PE Mapping* (page 44)).

#### **Properties**

Selecting **Properties** will open a properties dialog box for the selected entity from the process. The user is able to modify port and route properties in this dialog box.

Right-clicking on the **Memory Channels** sub-category under the **Channels** category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for each channel contains one command:

#### **Remove Selected Channels**

Selecting **Remove Selected Channels** will remove all entities of the selected type (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on a channel under the **Memory Channels** sub-category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for each channel contains two commands:

#### **Remove Channel(s)**

Selecting **Remove Channel(s)** will remove all selected entities of type (see Section 4.3.2 *PE Mapping* (page 44)).

#### **Properties**

Selecting **Properties** will open a properties dialog box for the selected entity from the process. The user is able to modify port, address, and route properties in this dialog box (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on the **FIFO Channels** sub-category under the **Channels** category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for **FIFO Channels** contains one command:

### Remove Selected Channels

Selecting **Remove Selected Channels** will remove all entities of the selected type (see Section 4.3.2 *PE Mapping* (page 44)).

Right-clicking on a channel under the **FIFO Channels** sub-category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for each channel contains two commands:

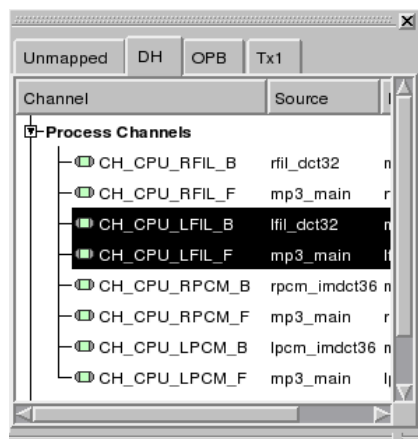
### Remove Channel(s)

Selecting **Remove Channel(s)** will remove all selected entities of type (see Section 4.3.2 *PE Mapping* (page 44)).

### Properties

Selecting **Properties** will open a properties dialog box for the selected entity from the process. The user is able to modify port, mapping, and route properties in this dialog box.

## 3.4. Channel Window



**Figure 3-4. Channel Window.**

In the Channel Window side bar, all the channels associated with each Bus and CE in the design are listed. Every Bus and CE is represented as a tab in the Channel Window. Unmapped channels are displayed in the Unmapped tab. The Channel Window is displayed in Figure 3-4.

Each Channel tab contains channels organized by channel categories: Process Channels, Memory Channels, and FIFO Channels.

### 3.4.1. Channel Window Process Channels

Right-clicking on the Process Channels category in the Channel Window opens a context-menu pop-up for the selected channel class. The context menu for Process Channels contains two commands:

#### Add Channel

Selecting Add Channel will open a dialog box for adding a channel. The user is able to specify the new channel's properties in this dialog box (see Section 4.3.4 *Channel Mapping* (page 58)).

#### Remove All Process Channels

Selecting Remove All Process Channels will remove all entities of the selected type from the tab (see Section 4.3.4 *Channel Mapping* (page 58)).

Right-clicking on a channel under the Process Channels category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for Process Channels contains three commands:

#### Add Channel

Selecting Add Channel will open a dialog box for adding a channel. The user is able to specify the new channel's properties in this dialog box (see Section 4.3.4 *Channel Mapping* (page 58)).

#### Remove Channel(s)

Selecting Remove Channel(s) will remove all selected entities of type (see Section 4.3.4 *Channel Mapping* (page 58)).

## Properties

Selecting **Properties** will open a properties dialog box for the selected entity from the process. The user is able to modify port and route properties in this dialog box.

### 3.4.2. Channel Window Memory Channels

Right-clicking on the **Memory Channels** category in the Channel Window opens a context-menu pop-up for the selected channel class. The context menu for **Memory Channels** contains two commands:

#### Add Channel

Selecting **Add Channel** will open a dialog box for adding a channel. The user is able to specify the new channel's properties in this dialog box (see Section 4.3.4 *Channel Mapping* (page 58)).

#### Remove All Memory Channels

Selecting **Remove All Memory Channels** will remove all entities of the selected type from the tab (see Section 4.3.4 *Channel Mapping* (page 58)).

Right-clicking on a channel under the **Memory Channels** category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for each channel contains three commands:

#### Add Channel

Selecting **Add Channel** will open a dialog box for adding a channel. The user is able to specify the new channel's properties in this dialog box (see Section 4.3.4 *Channel Mapping* (page 58)).

#### Remove Channel(s)

Selecting **Remove Channel(s)** will remove all selected entities of type (see Section 4.3.4 *Channel Mapping* (page 58)).

## Properties

Selecting **Properties** will open a properties dialog box for the selected entity from the process. The user is able to modify port, address, and route properties in this dialog box.

### 3.4.3. Channel Window FIFO Channels

Right-clicking on the FIFO Channels category in the Channel Window opens a context-menu pop-up for the selected channel class. The context menu for FIFO Channels contains two commands:

#### Add Channel

Selecting Add Channel will open a dialog box for adding a channel. The user is able to specify the new channel's properties in this dialog box (see Section 4.3.4 *Channel Mapping* (page 58)).

#### Remove All FIFO Channels

Selecting Remove All FIFO Channels will remove all entities of the selected type from the tab (see Section 4.3.4 *Channel Mapping* (page 58)).

Right-clicking on a channel under the FIFO Channels category in the PE Window opens a context-menu pop-up for the selected channel class. The context menu for each channel contains two commands:

#### Add Channel

Selecting Add Channel will open a dialog box for adding a channel. The user is able to specify the new channel's properties in this dialog box (see Section 4.3.4 *Channel Mapping* (page 58)).

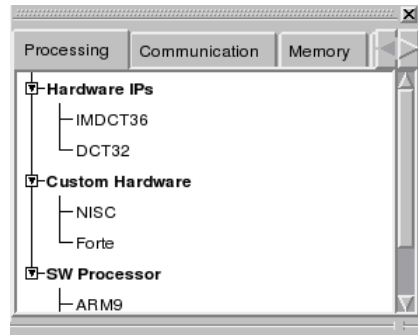
#### Remove Channel(s)

Selecting Remove Channel(s) will remove all selected entities of type (see Section 4.3.4 *Channel Mapping* (page 58)).

#### Properties

Selecting Properties will open a properties dialog box for the selected entity from the process. The user is able to modify port, mapping, and route properties in this dialog box.

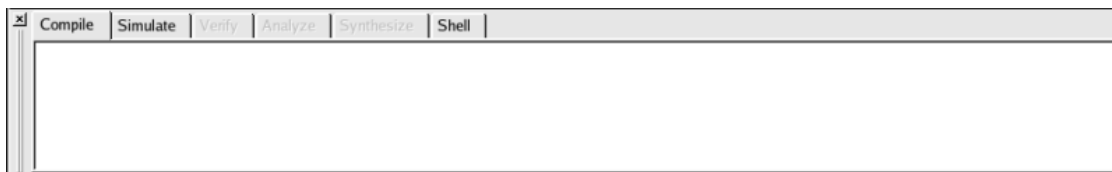
### 3.5. Database Window



**Figure 3-5. Database Window.**

In the Database Window side bar, all the database items associated with the design are listed. Each component from the database is represented as a tab in the Database Window. Each component contains a number of categories, which contain a number of database item types. The database item types can be dragged directly from the Database Window onto the Design Canvas to create an instance of that type for the design. The Database Window is displayed in Figure 3-5.

### 3.6. Output Window



**Figure 3-6. Output Window.**

The Output Window displays the information related to the process of ESE, such as logged status, diagnostic and error output of background commands. The Output Window is displayed in Figure 3-6. The Output Window contains six tabs: **Compile**, **Simulate**, **Verify**, **Analyze**, **Synthesize** and **Shell**. The **Compile** tab displays the log mes-

sages generated during preprocessing and parsing of the design file during Synthesis. The **Simulate** tab displays the log messages generated by the command line tools spawned by the main application GUI during simulation. The **Verify** tab displays the log messages generated by the command line tools spawned by the main application GUI during verification. The **Analyze** tab displays the log messages generated by the command line tools spawned by the main application GUI during analysis. The **Synthesize** tab displays the log messages generated by the command line tools spawned by the main application GUI during synthesis. Finally, the **Shell** tab contains an instance of the interactive ESE shell interpreter.

The Output Window is mainly for informational purposes and doesn't contain any button that users can click. Only the **Shell** tab allows to enter ESE commands interactively to be executed by the embedded scripting interpreter. In addition, all tabs support a context menu through which the user can save the contents of the tab to a file, cut, copy and paste text between a tab and other applications, toggle line wrapping, and clear or completely reset the tab. Furthermore, the **Shell** tab supports history substitution of previously entered commands via **Undo** and **Redo** context menu entries.

The Output Window can be detached or docked. Users can drag the window (by its title bar or handle) to the desired place. If the Output Window is detached, it can be floating and displayed anywhere on the desktop. If the Output Window is docked, it has to be attached to any of the borders of the Main Window.

### **3.7. Message Boxes**

As a result of certain actions, the ESE application will pop up message box dialogs for feedback to or input from the user about handling of special situations. Message boxes are used to provide informative messages and to ask simple questions. In general, there are two types of message boxes: error dialogs and information dialogs.



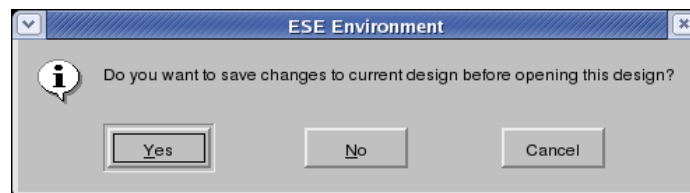
### 3.7.1. Error Dialogs



**Figure 3-7. Error dialog.**

If the application encounters an abnormal error situation in which user notification about the failure of the initiated action is required, an Error dialog will be popped up (Figure 3-7). The Error dialog displays an error message at the top-half of the Error dialog. At the bottom-half, an Error dialog contains one button: **Ok**. Clicking **Ok** will close the Error dialog and original dialog (if any) that prompted the message. After clicking, the original action that prompted the message is aborted and cancelled.

### 3.7.2. Information Dialogs



**Figure 3-8. Information dialog.**

If the application encounters an abnormal situation in which user notification is required and the user is given several choices on how to continue, an Information dialog will be popped up (Figure 3-8). An information message and associated question is displayed at the top-half of the dialog. The bottom-half of the dialog contains three buttons: **Yes**, **No**, and **Cancel**. Clicking **Yes** will accept the recommendation and do the corresponding action. Clicking **No** will not accept the recommendation and will not do the corresponding action but will continue the original action that prompted the message in the first

place. Finally, clicking **Cancel** will not do the recommended action and will also cancel the original action that prompted the message. Clicking one of above three buttons will close the Information dialog and original dialog (if any) that prompted the message.

## **Chapter 4. Functionality**

The functionality of ESE can be classified into the following categories: application, file handling, design-entity handling, and synthesis & simulation,

### **4.1. Application Preferences**

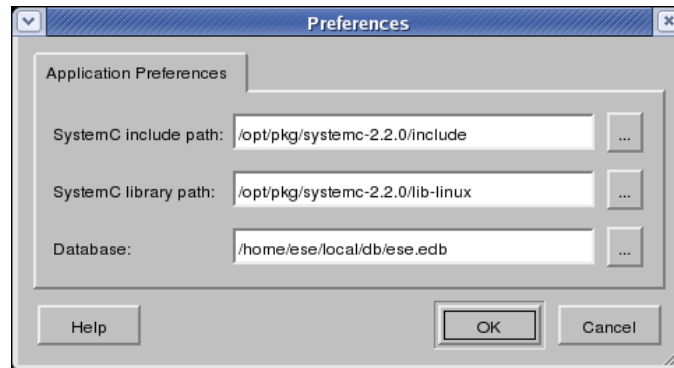
The main application of ESE supports a set of persistent application preferences. Application preferences are persistently stored across different invocations of the tool. In fact, application preferences are shared among all tools in the ESE environment, i.e. they are persistent across invocation of different tools at different times.

Application preferences are stored in both system-wide and user-specific locations (see Section 4.2.7 *Design Settings Editing* (page 39)). System-wide application preferences affect all users of ESE applications on the system. User-specific application preferences, on the other hand, are stored in a file in the user's Linux home directory. The application first reads the system-wide and then the user-specific settings, i.e. user-specific settings can override (if given) system-wide settings and if no user-specific settings are given, application settings default to the system-wide settings. If no system-wide settings are available, compiled-in defaults are used.

Application preferences in general provide the standard settings (paths, etc.) to use by default for the different parts of ESE applications.

Application preferences can be edited by the user by selecting **Main::Edit→Preferences...** This will pop-up the Edit Preferences dialog, which allow users to browse and specify individual settings. At the bottom of the Edit Preferences dialog, buttons **Ok** and **Cancel** are available. If users click the **Ok** button, all the edited preferences are saved. If users click the **Cancel** button, all the edited preferences are discarded. Either clicking **Ok** or **Cancel** button will close Preference dialog.

### 4.1.1. Application Preferences

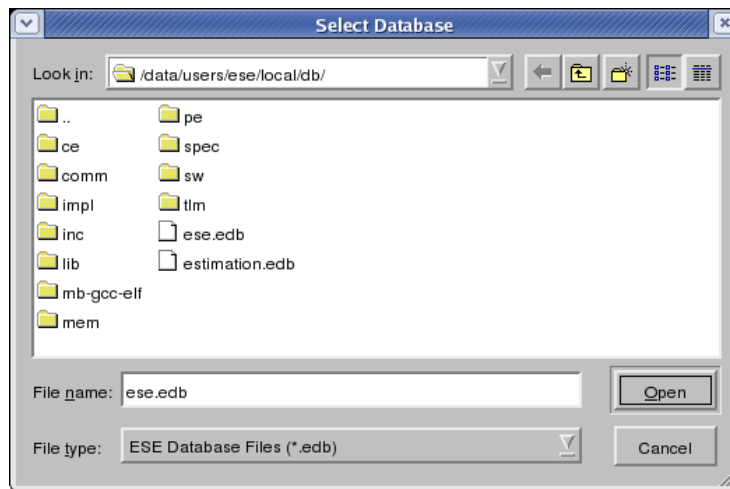


**Figure 4-1. Edit Preferences dialog.**

Database preferences define the location of the database EDB file for the Database Windows

The **Application** tab of the Edit Preferences dialog allows for viewing and selecting of database file path, as well as other include and library paths. The **Application** tab is shown in Figure 4-1.

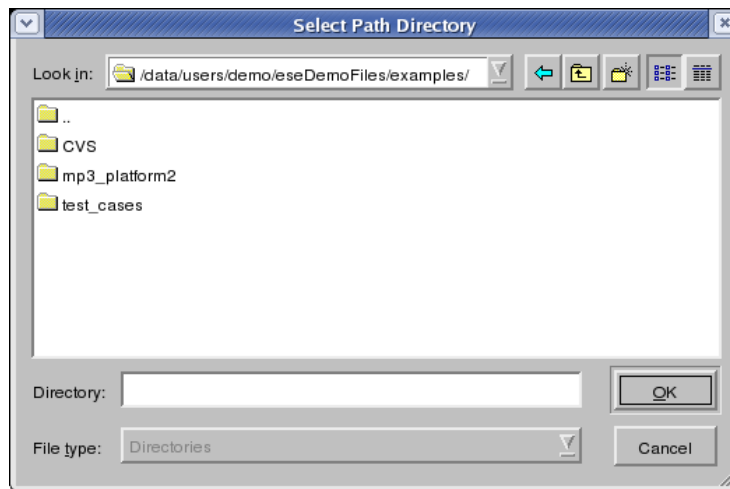
Users can type in the file name and path of the database in the **Application**'s line edit boxes. Besides typing in the file name, users can also select the names by using ... buttons next to the edit box. Clicking ... button will pop up a Database Selection dialog displayed in Figure Figure 4-2.



**Figure 4-2. Database Selection dialog.**

The Database Selection dialog allows users to choose and select existing database files on disk to use for the database. In the Database Selection dialog, users should first specify the database directory in Look-in box. The content of the directory will be automatically displayed in the display box in the center. The database type in the File Type box defaults to EDB files for databases but can be chosen by the user. All the database files with the specified type will be displayed in the display box. Users further type in the database name in File Name box. Finally, by clicking Open button, the database with the specified name will be selected. If users click Cancel button, then the action of database selection will be cancelled. Either clicking Open or Cancel button will close the Database Selection dialog.

Users can also type in the file name and path of the SystemC include and library paths in the Application's line edit boxes. Besides typing in the file name, users can also select the names by using ... buttons next to the appropriate edit box. Clicking ... button will pop up a SystemC Path Selection dialog displayed in Figure [xref linkend="fig-systemc-path-selection">](#).



**Figure 4-3. SystemC Path Selection dialog.**

The SystemC Selection dialog allows users to choose and select a directory on disk to use for the SystemC include path or the SystemC library path. By clicking Open button, the directory with the specified name will be selected. If users click Cancel button, then the action of database selection will be cancelled. Either clicking Open or Cancel button will close the Database Selection dialog.

## 4.2. Design Handling

Design handling deals with issues relating to manipulation of design and its corresponding files within ESE. It allows for tracking of design meta-data over the whole lifetime of a design. A design contains design-specific settings that can override or extend application-specific compiler settings (see Section 4.1 *Application Preferences* (page 29)). Specifically, a design contains the following information:

### Sources

A list of source files. The list of sources contains the union of all C and/or SystemC source files from which the models that are part of the design have been compiled. For each source file, the location (path) of the file on disk is stored in the design.

## Compiler settings

A set of design-specific options for preprocessing and parsing SystemC source files. Compiler settings contain include paths, import paths, compiler options, and macro defines and undefines. Design-specific compiler settings generally overwrite or extend the corresponding application-specific settings. In the case of paths, design paths are prepended to the standard paths defined in the application settings (i.e. they are prepended to the directory search list). In all other cases, options or macro defines/undefined are appended to the compiler command line after the standard options and macros defined in the application settings.

Designs are stored as ESE Data Structure (EDS, \*.eds) files on disk. The design file format is the same for all tools in the ESE environment, i.e. a design file can be read, modified and written by any ESE tool.

Design can be read from and saved as design files at any time in the ESE application. At any time, however, at maximum only one design can be open and loaded. While a certain design is open and loaded, its settings apply to all actions performed during that time. In addition, certain actions will automatically update and add data in the currently opened and loaded design.

**Note:** All paths in the design settings are defined to be relative to the location of the design file, i.e. relative paths in a design file are converted into absolute paths by appending the design file's directory during loading/opening of a design file. During saving/writing of design files, absolute paths are in turn converted back to relative paths if they point to a location below the target design file directory.

In order to deal with management of design files, ESE supports a set of file handling functions. Design handling includes opening, saving, and closing of design files on disk. Design handling is closely related to Design Canvas (Section 3.2 *Design Canvas* (page 12)) and Design Canvas Management (Section 4.7 *Window Management* (page 69)). In general, there is a one-to-one association between design models, design files on disk and design canvases in the Workspace. Each Design Canvas represents a view onto one loaded design file which in turn stores the data of one design model, and vice versa. For example, both file closing (Section 4.2.5 *Design Closing* (page 37)) and window closing (Section 4.7 *Window Management* (page 69)) will close the design file and the Design Canvas and unload the design from ESE's memory.

Specifically, file handling consists of the following tasks:

1. Design Creation to create a new design (see Section 4.2.1 *Design Creation* (page 34)).
2. Design Opening to open and load existing design files from disk (see Section 4.2.2 *Design Opening* (page 34)).
3. Design Saving to save the current design on disk (see Section 4.2.3 *Design Saving* (page 36)).
4. Design Closing to close the current design (see Section 4.2.5 *Design Closing* (page 37)).
5. Design Reloading to reload the current design's last saved instance (see Section 4.2.4 *Design Reloading* (page 37)).
6. Design Exporting to create a compressed archive file of the current design (see Section 4.2.6 *Design Exporting* (page 38)).
7. Design Settings to display and edit the settings of the opened design (see Section 4.2.7 *Design Settings Editing* (page 39)).
8. ESE Exiting to exit the ESE application (see Section 4.2.9 *ESE Exiting* (page 41)).

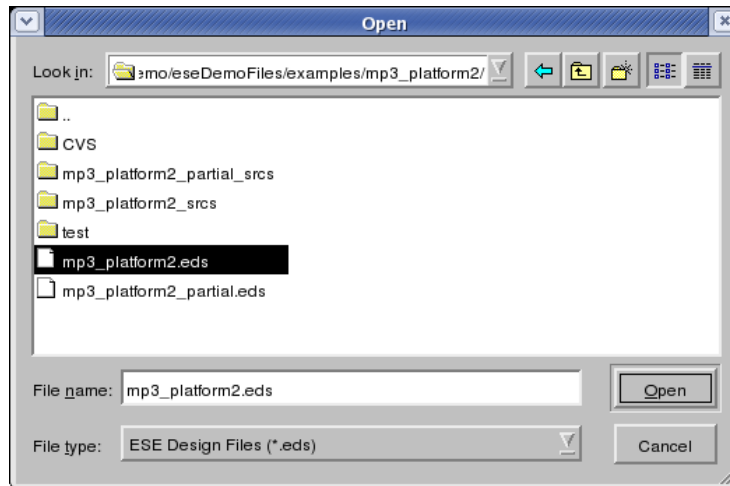
### 4.2.1. Design Creation

Users can create a new design by selecting **Main::File→New...** This action will clear all windows (Design Canvas, PE, Channel and Database Windows) in preparation for a new design.

**Error/Information Messages:** Assuming before design creation, users have opened another design in ESE, the currently opened design has been modified and the opened design is not saved yet. When users select **Main::File→New**, an Information dialog will be popped up querying whether to save the current design first before creating a new one. If the users accept the recommendation, a Design Saving action (see Section 4.2.3 *Design Saving* (page 36)) is performed first. In case of errors creating the design file (file errors, wrong file format), an error dialog with a corresponding error message is popped up. Upon confirming the error, the file creating action is cancelled.



## 4.2.2. Design Opening



**Figure 4-4. Design Open dialog.**

**Operation:** Users can open an existing design file on disk by selecting **Main::File→Open....** The Design Open dialog window will pop up in which users can choose and select an existing file on disk to open and load. The Design Open dialog is illustrated in Figure 4-4.

Users should first specify the directory of the file in **Look-in** box. The content of the directory will be automatically displayed in the display box in the center. The file type defaults to EDS files (\*.eds). All the files with the specified type will be displayed in the display box. Users then further select the file name in the **File Name** box. Finally, by clicking the **Open** button, the file with the specified name will be open. If users click the **Cancel** button, the action of file opening will be cancelled. Either clicking **Open** or **Cancel** button will close the File Open dialog.

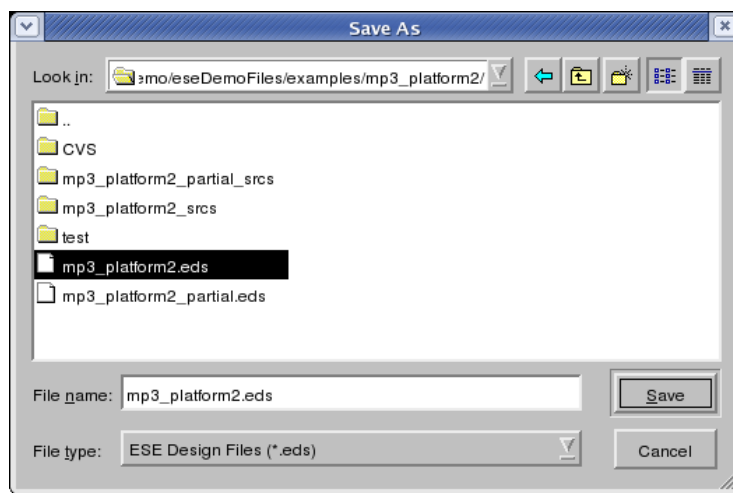
Opening and loading a design file will result in a corresponding design appearing in the Design Canvas.

**Error/Information Messages:** If the specified design file does not exist before clicking **Open** button, then clicking **Open** button has no effect.

In case of errors reading the design file from disk (file errors, wrong file format), an error dialog with a corresponding error message is popped up. Upon confirming the error, the Design Opening action is cancelled.

Assuming before design opening, users have opened another design in ESE, the opened design is modified and the opened design is not saved yet. When users open a different design, the Information dialog will be popped up to recommend users to save the previous design first and, if the recommendation is accepted, a Design Saving action will be performed. This is the same as the case in task Section 4.2.1 *Design Creation* (page 34).

### 4.2.3. Design Saving



**Figure 4-5. Design Save dialog.**

**Operation:** Users can save opened and loaded design files (Design Windows in the Workspace) by one of the following three methods:

1. Selecting **Main::File**→**Save** will save the file of the currently active Design Window using its current name.
2. Users can save the file of the currently active Design Canvas under any (new) name by selecting **Main::File**→**Save As....** The selection will pop up the Design Save dialog in which users can choose the directory and file name to save the design under. The Design Save dialog is shown in Figure 4-5.

In the File Save dialog, users should first specify the directory of the file in **Look-in** box. The content of directory will be automatically displayed in the display box in the center. The file type defaults to EDS files (\*.eds). All the files with the

specified type will be displayed in the display box. Users then further select the file name in **File Name** box. Finally, by clicking **Save** button, the current opened file will be saved as the file with the specified name. If users click **Cancel** button, then the action of file saving will be cancelled. Either clicking **Save** or **Cancel** button will close the Design Save dialog.

**Error/Information Messages:** When selecting **Main::File→Save As...** and specifying the file name of an existing design file on disk, an Information dialog will pop up asking whether to overwrite the existing file. If the users decline this, the design saving action will be cancelled.

When selecting **Main::File→Save** or **Main::File→Save As...**, errors may occur (file errors, e.g. if no space is available on the disk). In this case, an Error dialog as shown in Figure 3-7 will be popped up, corresponding error messages will be displayed, and the design saving action will be cancelled.

#### 4.2.4. Design Reloading

**Operation:** Users can save reload the current design file (Design Windows in the Workspace) by the following method:

1. Selecting **Main::File→Reload...** will save the file of the currently active Design Window using its current name.

**Error/Information Messages:** When selecting **Main::File→Reload...**, errors may occur (file errors, e.g. if no space is available on the disk). In this case, an Error dialog as shown in Figure 3-7 will be popped up, corresponding error messages will be displayed, and the design saving action will be cancelled.

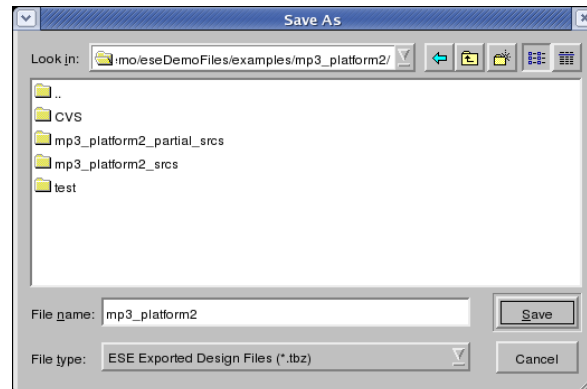
#### 4.2.5. Design Closing

**Operation:** Users can close the file and window of the currently active Design Window in the Workspace by selecting **Main::File→Close**. Closing a file will unload the design from memory and will close the corresponding Design Canvas in the Workspace.

**Error/Information Messages:** If the current design is modified and not yet saved, selecting **Close** will pop up an Information dialog which recommends to save the

current design first. If the users accept the recommendation, a design saving action (Section 4.2.3 *Design Saving* (page 36)) is performed before closing the design.

## 4.2.6. Design Exporting



**Figure 4-6. Design Export dialog.**

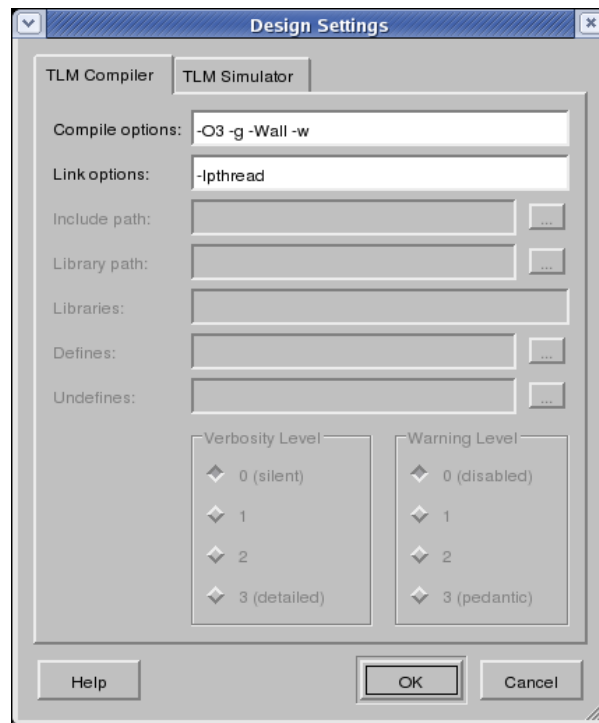
**Operation:** Users can export opened and loaded design files (Design Window) as compressed archive file (\*.tbz) on disk by selecting **Main::File→Export...** The selection will pop up the Design Export dialog in which users can choose the directory and file name to save the design under. The Design Export dialog is shown in Figure 4-6.

In the Design Export dialog, users should first specify the directory of the file in **Look in** box. The content of directory will be automatically displayed in the display box in the center. The file type defaults to ESE Exported Design Files (\*.tbz). All the files with the specified type will be displayed in the display box. Users then further select the file name in **File Name** box. Finally, by clicking **Save** button, the current opened file will be exported to the file with the specified name. If users click **Cancel** button, then the action of design exporting will be cancelled. Either clicking **Save** or **Cancel** button will close the File Export dialog.

**Error/Information Messages:** When selecting **Main::File→Export...** and specifying the file name of an existing file on disk, an Information dialog will pop up asking whether to overwrite the existing file. If the users decline this, the file exporting action will be cancelled.

When writing files to disk, errors may occur (file errors, e.g. if no space is available on the disk). In this case, an Error dialog will be popped up, corresponding error messages will be displayed, and the file exporting action will be cancelled.

### 4.2.7. Design Settings Editing

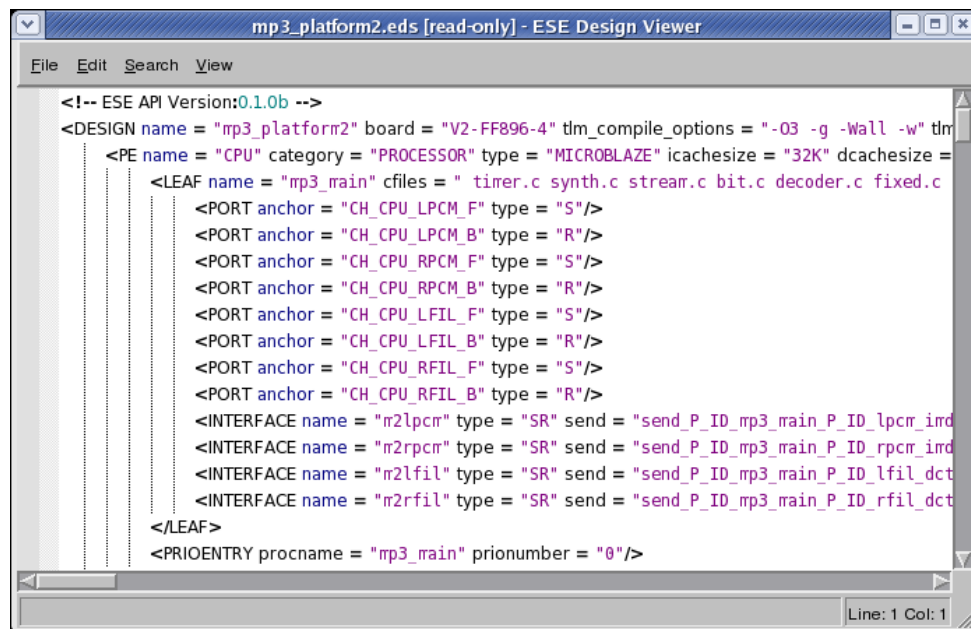


**Figure 4-7. Design Settings (TLM Compiler tab) dialog.**

**Operation:** Design setting allows users to edit design settings. Unlike application preferences editing in Section 4.1 *Application Preferences* (page 29), design setting apply only to the current design. Users start design settings editing by selecting **Main::File→Settings....** The selection will pop up the Design Settings dialog, which is displayed in Figure 4-7. In the Design Settings dialog, users can access and edit the TLM Compiler and TLM Simulator tags with corresponding settings stored in the design. The TLM Compiler tab contains line edit boxes for all compiler settings. The Compile Options and Link Options lines allow users to customize compilation and linking of design source files. The text in the Include Path and Import Path lines

defines the directory lists (separated by colons “:”) for the project-specific include and import paths, respectively. The text in the **Defines** and **Undefines** lines define the list of macro defines and undefines (separated by semicolons “;”), respectively. The text in the **Options** line defines the project’s compiler options/switches. Finally, **Verbosity Level** and **Warning Level** define verbosity level and warning level so that all tasks performed are logged and warning messages are enabled, respectively. See Section 4.1 *Application Preferences* (page 29) for more details about compiler settings. Similarly, the TLM Simulator tab includes the following options for output display of simulation (**Output**): No terminal, Terminal window, or outputting in the External console defined by users. Further, users can enable simulation logging by checking the appropriate check-box. Finally, line edit boxes **Simulation Options** and **Post-simulation command** define directives to the simulation engine during and after TLM simulation.

#### 4.2.8. Design Source Viewing



**Figure 4-8. Design Source Viewing dialog.**

**Operation:** The source file of the design can be viewed via **View**→**Source**.... The

result of View→Source... is shown in Figure 4-8.

### 4.2.9. ESE Exiting

**Operation:** Selecting Main::File→Exit will exit the ESE application and close the ESE GUI.

**Error/Information Messages:** If there is an open Design Canvas that is modified and not yet saved, an Information dialog will pop up querying whether to save the corresponding design. The users will be able to cancel the whole exit action via the corresponding dialog button. If the users accept the recommendation to save the file, a file saving action will be triggered (see Section 4.2.3 *Design Saving* (page 36)). Note that the design saving action can trigger additional Error dialogs which in turn can abort the whole exit operation in case of file errors during saving.

## 4.3. Transaction Level Modeling

Transaction Level Modeling is a process of implementing a system specification on a platform consisting of PEs and memories interconnected with busses and CEs (bridges, transducers), in order to generate a respective transaction level model (TLM) of the design. During TL Modeling, the designers allocate PEs and memories, busses and CEs and connect them into an integral system platform. During mapping, the designers map computation processes to the PEs and end-to-end communication channels to the network of PEs, CEs and busses. Processes are units of computation in the specification. The end-to-end channels connect processes to enable interprocess data exchange, or connect a process with the memory for data storing. Specifically, Transaction Level Modeling consists of the following tasks:

1. PE Allocation to allocate and select PEs/memories from the PE database in order to assemble the system's computing architecture (see Section 4.3.1 *PE Allocation* (page 42)).
2. PE Mapping to map the design's computation entities (or processes) to the selected PEs (see Section 4.3.2 *PE Mapping* (page 44)).
3. Network Allocation to allocate, select and define the communication network topology (see Section 4.3.3 *Network Allocation* (page 49)).

4. Channel Mapping to map the design's global, system-level channels to the selected network of PEs, busses and CEs (see Section 4.3.4 *Channel Mapping* (page 58)).
5. TLM synthesis to automatically generate an Transaction Level Model from the given specification based on the decision made during the allocation of components and application-to-platform mapping (see Section 4.4 *TLM Synthesis* (page 63)).

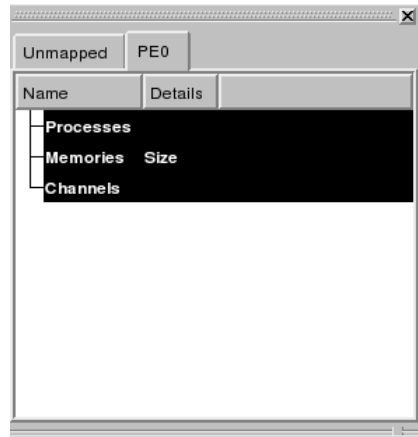
In order to perform TL Modeling, not all the tasks described in previous sections need to be done. However, some tasks must be executed and must be executed in a certain order. These mandatory tasks and their execution sequence are:

1. Design Creation or Design Opening.
2. Preferences Editing and Design Settings Editing.
3. PE Allocation.
4. PE Mapping.
5. Network Allocation.
6. Channel Mapping.
7. TLM Synthesis.
8. Design Saving and/or ESE Exiting.

Note that steps 3 through 7 can be performed repeatedly in a loop in order to generate multiple candidate TL models in one design modeling session.

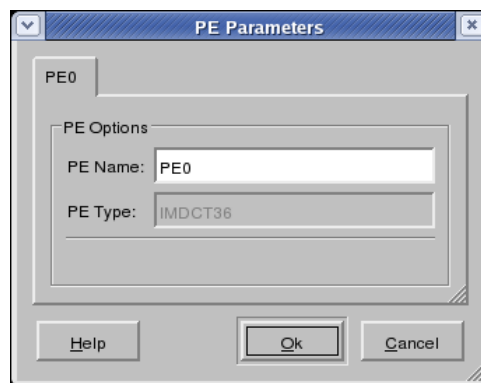


### 4.3.1. PE Allocation



**Figure 4-9. PE Allocation result.**

Users can select PEs/memories out of the PE database in order to allocate and assemble the system architecture. PE allocation information is stored in the design itself (\*.eds) as an annotated Data Structure component.



**Figure 4-10. PE Parameters dialog.**

**Operation:** In order to do PE allocation, users first select Processing tab in the Database Window. The Processing tab contains the PE category table, with each row representing one category of PEs in the database. For example, row **SW Processors** contains

all the general-purpose processors in the database. The supported EDS categories are Hardware IPs, Custom Hardware or SW Processor. The users add the PE to the design's platform by dragging the desired EDS component from its category and dropping it into the Design Canvas. This creates a PE in the Design Canvas with the default PE\_name. The result of a PE Allocation action is shown in Figure 4-9.

In the PE Window, list of tabs with currently allocated PEs will be shown (Figure 4-9). Each tab lists the names of Processes, Memories and Channels belonging to that PE.

PEs can be parametrized after instantiation by right-clicking on the component in the Design Canvas. The Component Parameter dialog will be popped up (see Figure 4-10). In this dialog, the users can enter and confirm all parameters for the given component instance to be allocated. Users can enter any value for any parameter (within the value range allowed by the component) by clicking into each parameter's value field in the dialog. Clicking the **Ok** button of the dialog will generate a new customized component type with the selected parameters and will then allocate a new instance of this parametrized type. Clicking the **Cancel** button aborts component parametrization.

In order to remove a PE from the design's platform, users can right-click on the target PE to be removed in the Design Canvas and select the **Remove PE** option. Clicking on the **Remove PE** will remove the selected PE from the list of allocated PEs.

**Error/Information Messages:** During PE editing, if users try to give PEs a name which is already used as the name of another PE in the design, an Error dialog will be popped up with a corresponding error message and a query to continue without saving changes. Answering 'no' will close the Error dialog. Answering 'yes' will abort and cancel the PE Parameters editing operation.

During PE adding, when adding a PE, the selected PE type is read from the database. In case of errors during database opening (e.g. file errors or wrong file format), an Error dialog will be popped up and the PE adding operation will be aborted.

### **4.3.2. PE Mapping**

In order to implement the computation in the design model on the allocated computation architecture consisting of PEs and memories, users have to be able to map the processes, variables (memory) and channels in the specification onto the allocated PEs. Hence, mapping consists of separate process mapping, memory mapping, and channel mapping tasks.

### 4.3.2.1. Process Mapping

Process mapping allows for mapping of process types/classes in the design onto allocated PEs, i.e. process mapping information is stored as annotations at the process classes in the design. A process is mapped to the PE by right-clicking on the corresponding PE tab in the PE Window and selecting Add Process option. This creates a process listing in the PE tab with the default process name. Process mapping information consists of process name, source files and process ports and it can be accessed for editing with right-clicking on the process listing.

#### Process Renaming

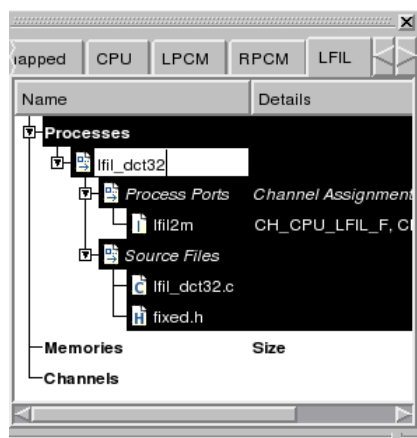
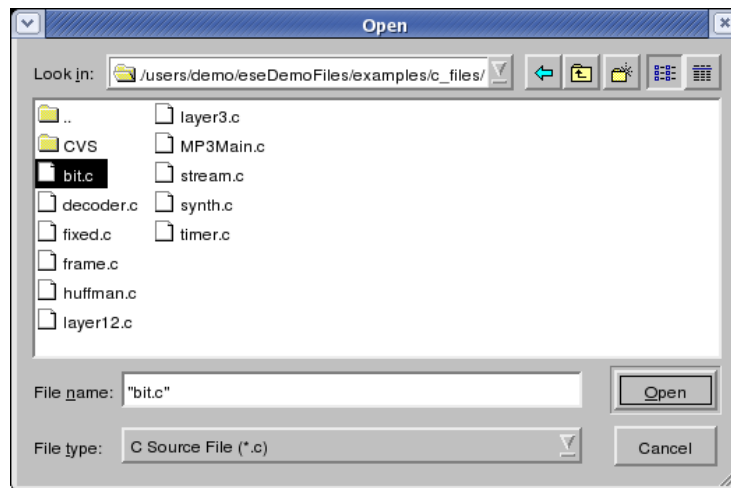


Figure 4-11. Process Renaming dialog.

Process renaming is accessed by right-clicking on the process listing and selecting Rename Process option. The process name line box can be edited until key Enter is pressed. Process renaming is shown in Figure 4-11.

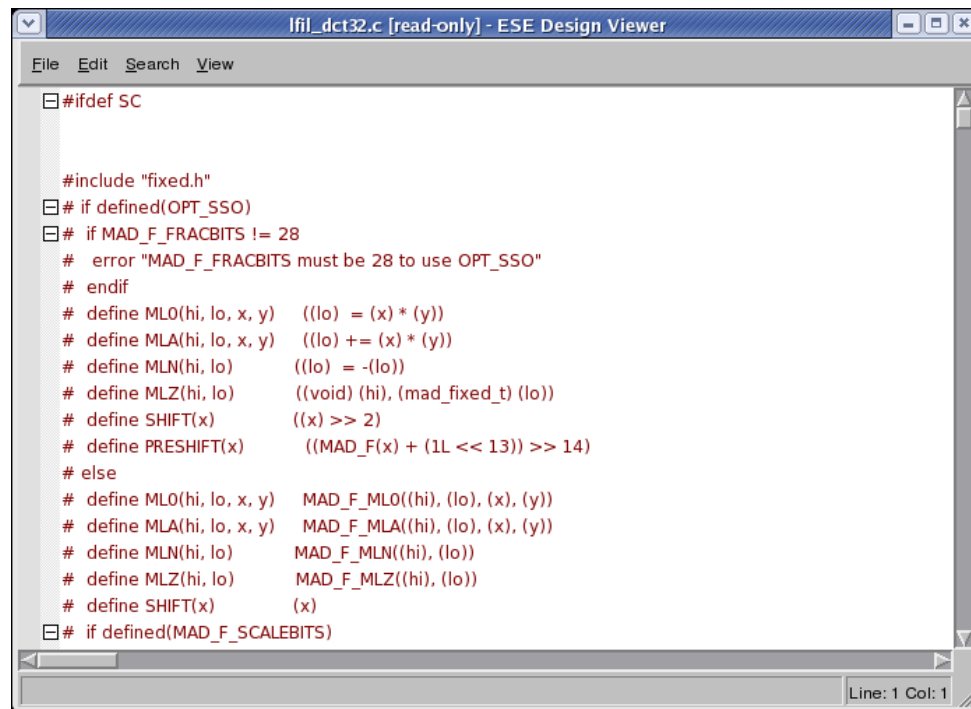
## Adding Source File(s) to the Process



**Figure 4-12. Adding Sources to a Process (C File) dialog.**

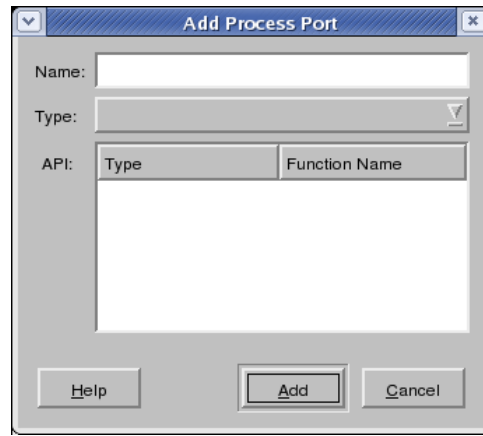
The users can add source files (\* .c and \* .h) to the process by right-clicking on the process listing and selecting Add .C File(s) and Add .H File(s) options, respectively. An Open dialog will be popped up (see Figure 4-12). In this dialog, users should first specify the file(s) directory in Look-in box. The content of the directory will be automatically displayed in the display box in the center. The file(s) type in the File Type box defaults to C source files (\* .c) or C header files (\* .h), depending on the selected option. All the source/header files with the specified type will be displayed in the display box. Users further type in the file name(s) in File Type box. Finally, by clicking Open button, the file(s) with the specified name(s) will be selected. If users click Cancel button, then the action of database selection will be cancelled. Either clicking Open or Cancel button will close the Open dialog.

## Viewing Source File(s) of the Process

**Figure 4-13. Adding Sources to a Process (C File) dialog.**

The users can view the source file(\*.c and \*.h) of the process by right-clicking on the process listing and selecting View Source. An ESE Design Viewer dialog will be popped up (see Figure 4-13). In this dialog, users can view the source file textually and search for keywords. Choosing Main::File→Close will close the ESE Design Viewer dialog.

### Adding Process Port(s) to the Process



**Figure 4-14. Adding a Process Port to a Process dialog.**

The users add process ports to the process by right-clicking on the process listing and selecting Add Process Port option. An Add Process Port dialog will be popped up, as shown in Figure 4-14. The users can name the process port in Name line box, and define its type by selecting one option in the Type drop box. Upon selection, the API box will automatically display the selected type(s) of API(s). The users can then name the API(s) belonging to that port by double-clicking and writing the API functions in the appropriate lines of the display box. Finally, by clicking Add button, the process port with the specified API(s) will be selected. If users click Cancel button, then the action of creating a process port will be cancelled. Either clicking Open or Cancel button will close the Add Process Port dialog.

#### 4.3.2.2. Local Memory Mapping

Memory mapping allows for mapping of variable instances in the design into exposed memories of allocated regular PEs. An exposed memory is added to the PE by right-clicking on the corresponding PE tab in the PE Window and selecting Add Exposed Memory option. This creates a memory listing in the PE tab with the default memory name. Memory mapping information consists of memory name and size and it can be accessed for editing with right-clicking on the memory listing.

### 4.3.2.3. Local Channel Mapping

Channel mapping attributes an end-to-end channel to a pair of processes. Depending on the selected route, a channel can be either local (i.e. belonging to a single PE), or global (i.e. connecting processes of different PEs), mapped to the network of busses and CEs. Local and global channel mapping is uniformly described in Section 4.3.4 *Channel Mapping* (page 58).

### 4.3.3. Network Allocation

Network allocation and connection information is stored in the design itself (\*.eds) as an annotated Data Structure allocation and connection tables.

Network topology includes an interconnection of communication busses and communication elements (CEs). The end-to-end channels that implement communication between processes are then mapped to the routes of busses and CEs connecting those processes. Hence, network allocation consists of separate bus allocation, CE allocation, network connecting and channel mapping tasks.

#### 4.3.3.1. Bus Allocation

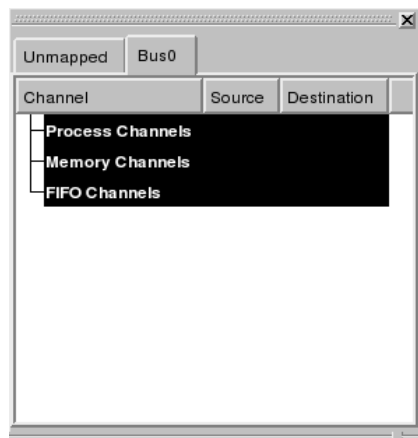
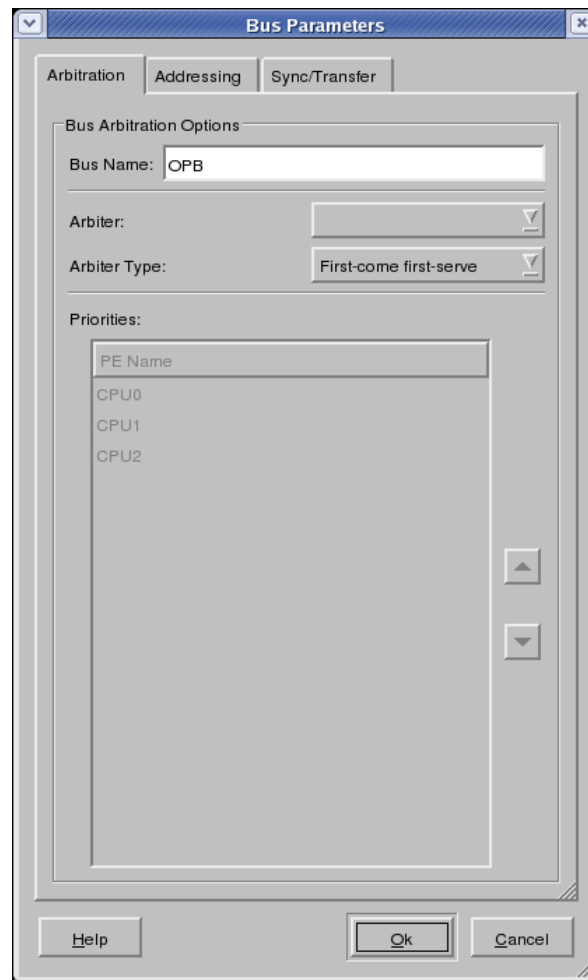


Figure 4-15. Bus Allocation result.

**Operation:** In order to allocate a bus, users first select Communication tab in the Database Window. The Communication tab contains the communication category table, with each row representing one category of communication media in the database. For example, category **Bus** includes all busses supported with the database. The EDS communication categories are Network, Bus and Link. The user adds the communication component to the design's platform by dragging the desired EDS component from its category and dropping it into the Design Canvas. This creates a bus in the Design Canvas with the default Bus\_name. The result of a Network Allocation (adding a bus) action is shown in Figure 4-15.

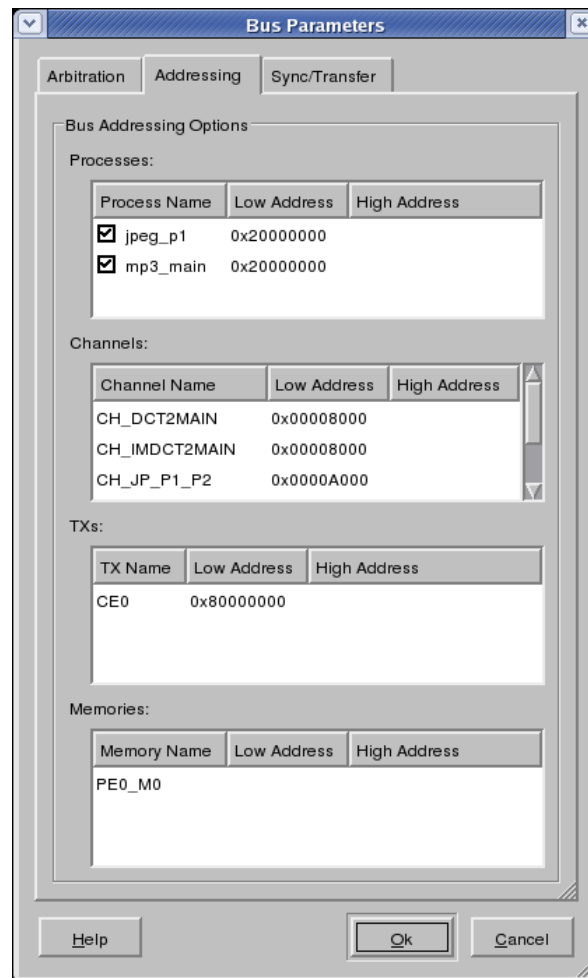
In the Channel Window, list of tabs with currently allocated busses will be shown (Figure 4-15). Each tab lists the names of Process Channels, Memory channels and FIFO channels belonging to that bus.



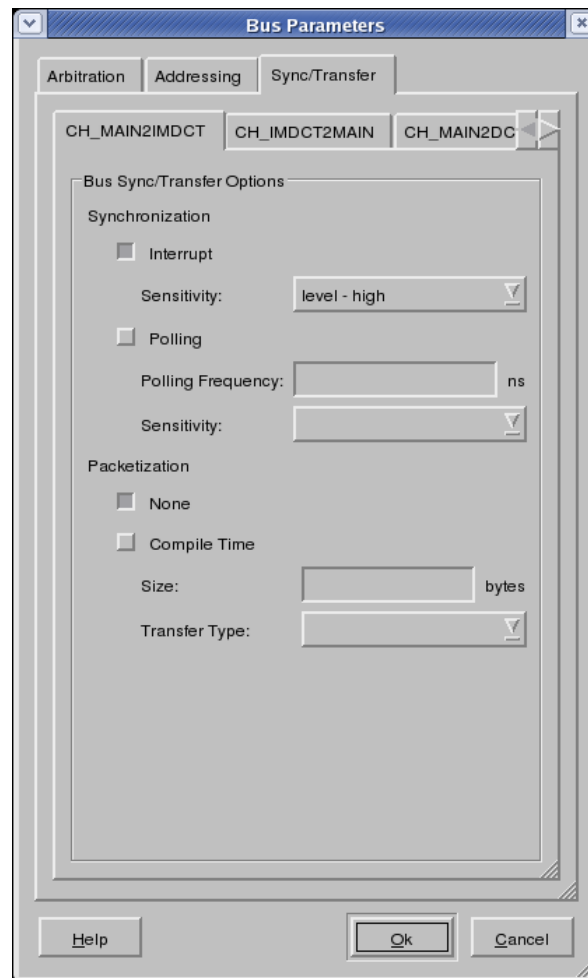


**Figure 4-16. Bus Parameters dialog.**

Busses can be parametrized after instantiation by right-clicking on the bus component in the Design Canvas. The Component Parameter dialog will be popped up (see Figure 4-16). In this dialog, the user has to enter and confirm all parameters (within categories of Arbitration, Addressing and Sync/Transfer) for the given bus component instance. For example, addressing the components connected to the bus is done within the tab Addressing (see Figure 4-17). Users can enter values for Low and High Address for any component (a Channel, CE port or a Memory) by clicking into each parameter's value field in the dialog. To set the synchronization type for each channel, the user has to click on the Sync/Transfer tab (see Figure 4-18). Here, synchronization and packetization options are set per channel.



**Figure 4-17. Bus Addressing dialog.**



**Figure 4-18. Bus Synchronization dialog.**

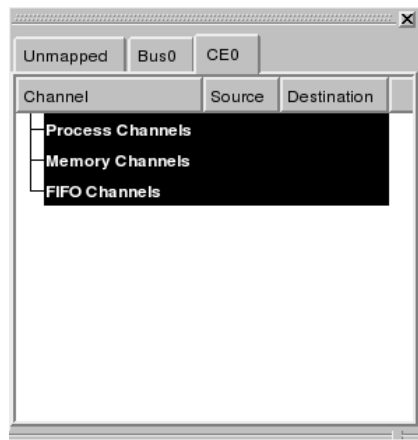
Clicking the **Ok** button of the dialog will generate a new customized component type with the selected parameters and will then allocate a new instance of this parametrized type. Clicking the **Cancel** button aborts component parametrization.

In order to remove a bus from the design's platform, users can right-click on the target bus to be removed in the Design Canvas and select the **Remove Bus** option. Clicking on the **Remove Bus** will remove the selected Bus and all its connections from the platform.

**Error/Information Messages:** During bus editing, if users try to give busses a name which is already used as the name of another bus in the design, an Error dialog will be popped up with a corresponding error message and a query to continue without saving changes. Answering 'no' will close the Error dialog. Answering 'yes' will abort and cancel the Bus Parameters editing operation.

When adding a bus, the selected bus type is read from the database. In case of errors during database opening (e.g. file errors or wrong file format), an Error dialog will be popped up and the PE adding operation will be aborted.

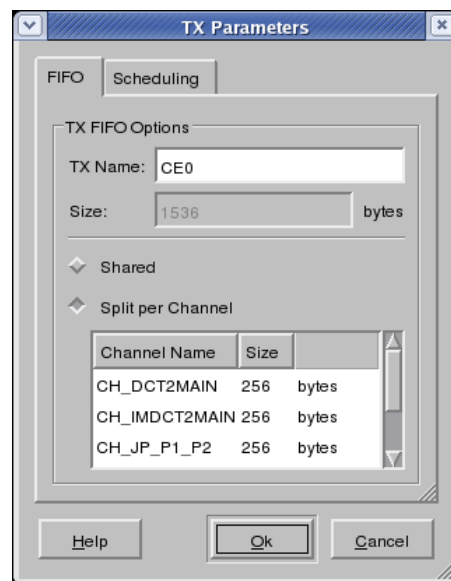
#### 4.3.3.2. CE Allocation



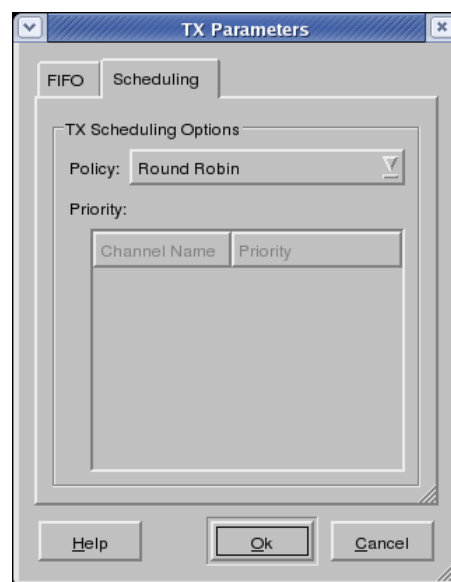
**Figure 4-19. CE Allocation result.**

**Operation:** In order to allocate a CE, users first select CE tab in the Database Window. The CE tab contains the CE category table, with each row representing one category of CEs in the database. For example, category **Bridge** includes all bridges supported with the database. The EDS communication categories are Router, Transducer and Bridge. The user adds the CE component to the design's platform by dragging the desired EDS component from its category and dropping it into the Design Canvas. This creates a CE in the Design Canvas with the default CE\_name. The Network Allocation (adding a CE) is shown in Figure 4-19.

In the Channel Window, list of tabs with currently allocated CEs will be shown (Figure 4-19). Each tab lists the names of Process Channels, Memory channels and FIFO channels belonging to that CE.



**Figure 4-20. CE Parameters dialog.**



**Figure 4-21. CE Scheduling dialog.**

CEs can be parametrized after instantiation by right-clicking on the CE component in the Design Canvas. The Component Parameter dialog will be popped up (see Figure 4-20). In this dialog, the user has to enter and confirm all parameters (within categories of

FIFO and Scheduling) for the given bus component instance. Users can enter any value for any parameter (within the value range allowed by the component) by clicking into each parameter's value field in the dialog. There are two tabs = Fifo and Scheduling. In the Fifo tab, the size and partition types are set. In the Scheduling tab (see Figure 4-21), the transducer scheduling policy is set. Clicking the **Ok** button of the dialog will generate a new customized component type with the selected parameters and will then allocate a new instance of this parametrized type. Clicking the **Cancel** button aborts component parametrization.

In order to remove a CE from the design's platform, users can right-click on the target component to be removed in the Design Canvas and select the **Remove CE** option. Clicking on the **Remove CE** will remove the selected CE and all its connections from the platform.

**Error/Information Messages:** During CE editing, if users try to give CEs a name which is already used as the name of another CE in the design, an Error dialog will be popped up with a corresponding error message and a query to continue without saving changes. Answering 'no' will close the Error dialog. Answering 'yes' will abort and cancel the CE Parameters editing operation.

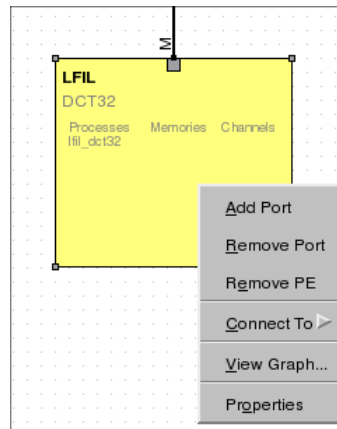
When adding a CE, the selected CE type is read from the database. In case of errors during database opening (e.g. file errors or wrong file format), an Error dialog will be popped up and the PE adding operation will be aborted.

#### **4.3.3.3. Connecting the network**

The network is constructed by connecting PEs and CEs to the busses. This process is

done with the following operations:

### Port Adding



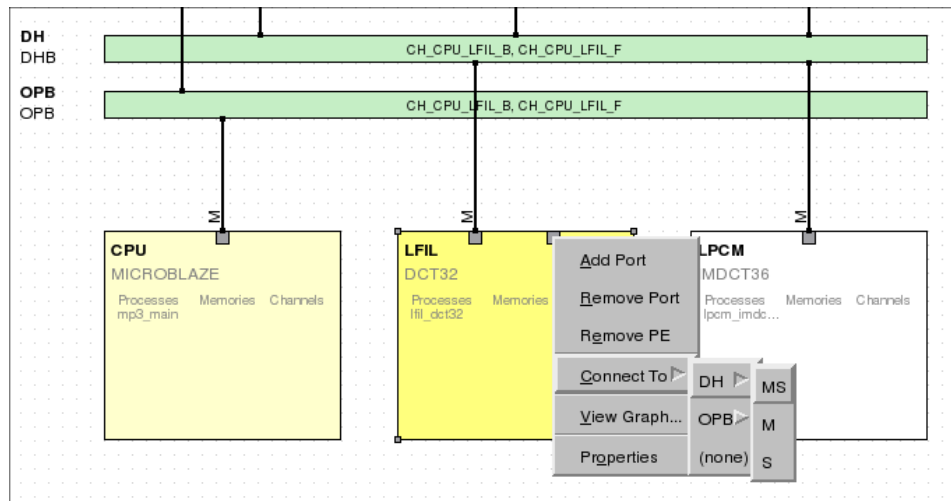
**Figure 4-22. Port Adding dialog.**

By right-clicking onto a PE or CE in the Design Canvas and selecting Add Port option, the user attributed the communication port to that PE/CE. The Port Adding is shown in Figure 4-22.

### Remove Port

Right-clicking onto a PE's or CE's port and selecting the Remove Port from the context menu will remove that port from the corresponding PE or CE.

## Connecting to the Bus



**Figure 4-23. Connecting to the bus dialog.**

Users can connect the PE/CE to the bus (named Bus\_name) by right-clicking on the created PE/CE's port and selecting **Connect toBus\_name** option. Generally, PE/CE ports can be connected to buses either as bus master (M), bus slave (S) or as combined bus master/slave (MS), as shown in Figure 4-23.

### 4.3.4. Channel Mapping

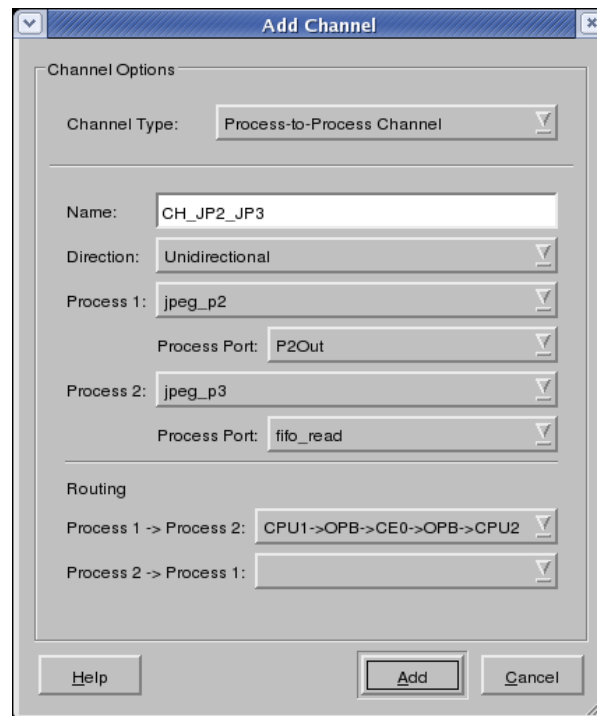


**Figure 4-24. Add Channel context menu.**



Channel mapping attributes an end-to-end channel to a pair of processes. Creating a channel begins by right-clicking onto a Channel Window and selecting Add Channel option. This action is shown on in Figure 4-24. The Channel Type dropbox allows the users to select among the following types of channels: Process-to-Process Channel, Memory Channel and FIFO Channel.

#### Process-to-Process Channel



**Figure 4-25. Process-to-Process Channel dialog.**

Process-to-Process Channel is defined with the inputting the values of the following parameters, as shown in Figure 4-25:

1. **Name** line box defines a unique name identifier for the channel.
2. Dropdown **Direction** provides options of Unidirectional and Bidirectional channel. Unidirectional channels only transfer data from **Process 1** to **Process 2**.
3. If the channel is defines as Unidirectional, dropdown **Process 1** allows the users to select the sending process. Otherwise, it defines the first process in the communicating process pair.

4. Dropbox **Process Port** provides the users with the list of available ports of the selected process. Available ports have no previously assigned channels to them and are, if the channel is Unidirectional, defined as sending or writing ports.
5. Similarly to **Process 1**, dropbox **Process 2** defines either process receiver, or the second process in the communicating process pair.
6. **Process Port** lists previously unassigned ports of the selected process. If the channel is Unidirectional, the listed ports are defined as receiving or reading ports.
7. Finally, two dropboxes for routing give the users the list of available routes between processes. If the channel is Unidirectional, only one of the dropboxes is active.

### Memory Channel

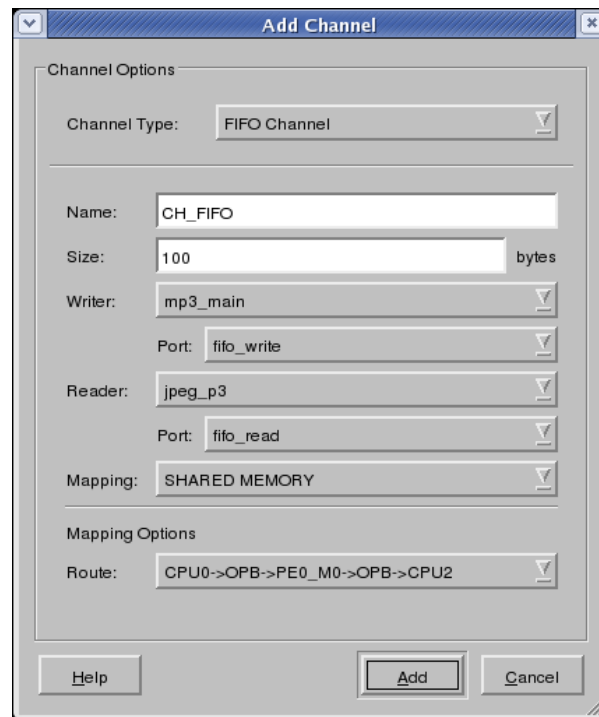


**Figure 4-26. Memory Channel dialog.**

Memory Channel is a channel that connects a process with the Memory element. The channel is defined with the following parameters, as shown in Figure 4-26:

1. **Name** line box defines a unique name identifier for the channel.
2. **Dropbox Direction** allows users to define a channel as: Read only, Write only or Read/write channel.
3. Users can select the process that accesses the Memory from the list of processes presented in the dropbox **Process**.
4. **Dropbox Process Port** provides the users with the list of available ports of the selected process. Available ports have no previously assigned channels to them and are defined as reading and/or writing ports (depending on the selection in channel **Direction**).
5. Users can define the Memory that Process reads from and/or writes into by selecting from the dropbox **Memory**. Only memories accessible (i.e. exposed) to the channel are listed here.
6. **Low Address** and **High Address** line boxes allow the user to define the address range of the Memory that is accessible to the Process via this channel.
7. Finally, two dropboxes for routing give the users the list of available routes between a Process and a Memory. If the channel is Read only, the dropbox **Memory->Process** is the only one active for selection. If the channel is Write only, the active dropbox is **Process->Memory**.

## FIFO Channel

**Figure 4-27. FIFO Channel dialog.**

FIFO Channel is defined with the following parameters, as shown in Figure 4-27.

1. Name line box defines a unique name identifier for the channel.
2. Next, the line box **Size** defines the storage capacity of the FIFO channel. (i.e. the depth of the FIFO queue).
3. The sending process is defined with selection from the dropbox **Writer**, and the corresponding (i.e. writing) process port can be selected from the dropbox **Port**.
4. Similarly, the reading process is defined by selecting from the dropbox **Reader**, with the dropbox **Port** defining its (reading) port.
5. Mapping line box allows the user to define whether the FIFO will be mapped to the **WRITER PE** or **READER PE**.
6. Finally, the dropbox **Route** gives the users the list of available routes between two processes. Since FIFO channel is by definition unidirectional, only one

dropbox defines the route.

### Reviewing Channel Properties

After creating a channel, users can access channel properties by right-clicking on the listing of the channel whose properties they wish to review and selecting Properties option. Channel listings Process Channels, Memory Channels and FIFO Channels for are located in the Channel Window.

### Removing a Channel

Users can remove created channels by right-clicking on the channel listing in the Channel Window and selecting Remove Channel option. This action releases all the ports that were assigned to the removed channel.

In order to add a defined channel to the design, users can edit the listed channel parameters and click the Add button. If users click Cancel button, then all unsaved user selections will be cancelled. Either clicking the Add or Cancel button will close the Add Channel dialog.

Every channel connected to a system bus must be assigned an address range. Base addresses and address masks define the address space occupied by the channel on the bus, i.e. they define the address decoding to be performed for that channel. Note that address ranges will later be used for automatic address selection during bus parameter assignment. The addresses of channels mapped to the same bus must not overlap.

**Error/Information Messages:** There are several errors that can happen during bus or CE allocation:

1. When adding a bus or CE to the allocation via the Bus or CE Selection dialog, the selected bus/CE type is read from the database. In case of database read errors (file errors, database format errors) during this operation, an Error dialog will be popped up and the Bus/CE Adding operation aborted.
2. In addition, if during port name editing users try to give ports a name which is already used as the name of another port of the same PE/CE, a corresponding Error dialog will be shown and the renaming operation is cancelled.

## **4.4. TLM Synthesis**

### **4.4.1. Generate Functional TLM**

Generation of the functional TLM includes generating SystemC code for the created design, compiling and linking the design files into an executable `tlm` binary. The code generation is started by selecting **Main::Synthesis→Generate Timed TLM** option in the main menu.

### **4.4.2. Generate TLM**

Generation of the timed TLM includes generating SystemC code annotated with the estimated values of execution time for computation and communication, compiling and linking the design files into an executable `tlm`. The code generation is initiated by selecting **Main::Synthesis→Generate Timed TLM**.

## **4.5. TLM Validation**

### **4.5.1. Simulate Functional TLM**

Simulation of the functional TLM is started by selecting **Main::Validation→Simulate Functional TLM**. This will pop-up the Simulation Output Window dialog, which allow users to validate the correctness of the functional TLM execution.

### **4.5.2. Simulate Timed TLM**

Simulation of the timed TLM is started by selecting **Main::Validation→Simulate Timed TLM**. This will pop-up the Simulation Output Window dialog, which allow users to validate the correctness of the timed TLM execution.

## **4.6. Performance Analysis**

Following a successful timed TLM simulation, users can access and analyze the esti-

mated performance of the created design at the transaction level of communication. The total cycles for the system simulation is shown in the output terminal, and it is also recorded in the file {project\_name}.cyc. The performance of PEs, CEs and bus components in the design model can be reviewed by right-clicking on the component of interest in the Design Canvas and selecting the View Graph... option.

#### 4.6.1. PE Performance Analysis

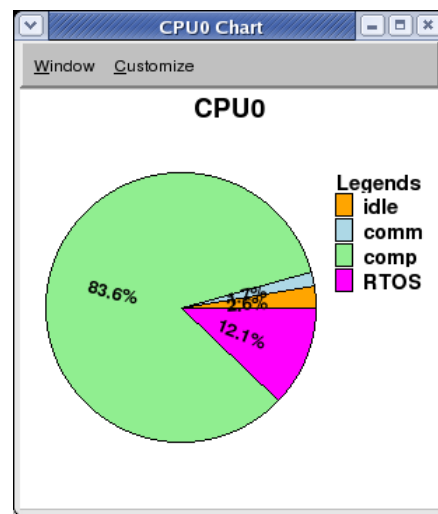


Figure 4-28. PE Performance Analysis dialog.

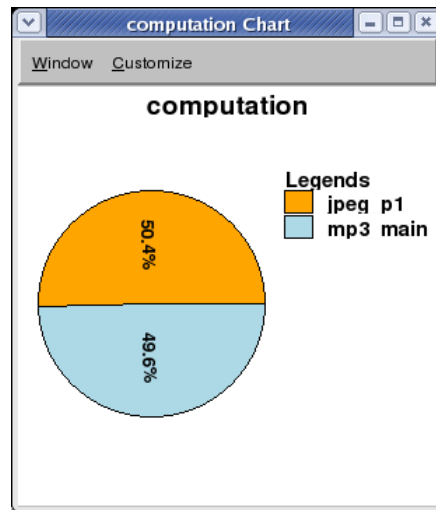


Figure 4-29. PE Computation graph dialog.

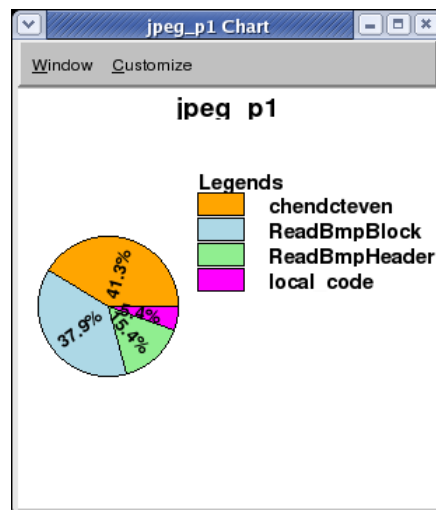


Figure 4-30. Process Computation graph dialog.

PE Performance Analysis graph is accessed with right-clicking on that PE in the Design Canvas and selecting View Graph... option. This action pops-up a pie chart of the selected PE's performance, divided into the categories of idle time, Real-Time Operating System (RTOS) overhead time, time spent on communication and time spent on computation (idle, RTOS, comm, comp, respectively). The PE performance pie chart is shown in Figure 4-28. By clicking on the computation slice, another pie chart is shown (see Figure 4-29). It displays the processes slice in the PE computation time. By further



clicking on a process, the user can see the different functions which compose the process (see Figure 4-30). The pie chart can be customized by accessing **Main::Customize** menu. The available options in viewing the performance graph are as follows:

No Explode / Medium Explode / Heavy Explode

No Explode is a default option for viewing a pie chart, which differentiates the separate slices of the pie by color alone. Users can emphasize the separation between pie slices by selecting Medium or Heavy Explode, which, in addition to use of color, injects extra space between pie slices.

Quantifying PE Performance

PE's performance in terms of idle time and times spent on communication and computation can be quantified with a ratio, their absolute values (in clock cycles), percentage values or with their respective idle/comm/comp labels.

Closing Performance Analysis Window

The pie chart window is closed by selecting **Main::Window**→**Close** menu.

## 4.6.2. Bus Performance Analysis

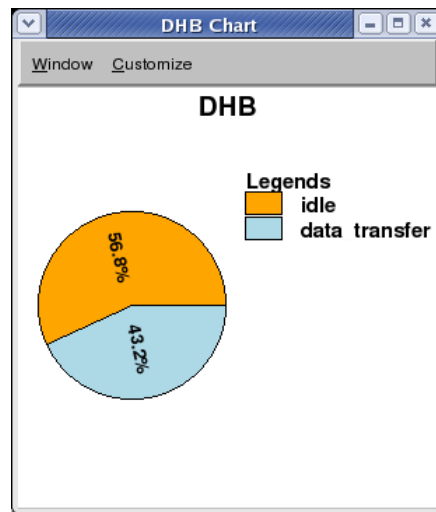
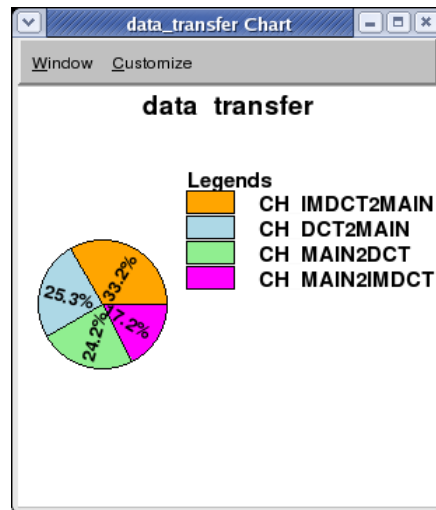


Figure 4-31. Bus Performance Analysis dialog.



**Figure 4-32. Bus Data Transfer Analysis dialog.**

Bus Performance Analysis graph is accessed with right-clicking on the desired bus in the Design Canvas and selecting View Graph... option. This action pops-up a pie chart of the selected bus' performance, divided into the categories of idle time, time spent on fetching instruction/data (if the Program/Data is stored in the external memory) and time spent on transferring messages between processes (idle, Program/Data, data transfer, respectively). The bus performance pie chart is shown in Figure 4-31. By clicking on the Data Transfer slice, the breakdown of the data transfer by channels is shown (see Figure 4-32). The pie chart can be customized by accessing Main::Customize menu. The available options in viewing the performance graph are as follows:

#### No Explode / Medium Explode / Heavy Explode

No Explode is a default option for viewing a pie chart, which differentiates the separate slices of the pie by color alone. Users can emphasize the separation between pie slices by selecting Medium or Heavy Explode, which, in addition to use of color, injects extra space between pie slices.

#### Quantifying Bus Performance

The bus performance in terms of idle time and times spent on fetching program in-

structions/data and data transfer can be quantified with a ratio, their absolute values (in clock cycles), percentage values or with their respective labels.

#### Closing Performance Analysis Window

The pie chart window is closed by selecting **Main::Window**→**Close** menu.

### **4.6.3. CE Performance Analysis**

CE Performance Analysis graph is accessed with right-clicking on the desired CE in the Design Canvas and selecting **View Graph...** option. This action pops-up a pie chart of the selected CE's performance, divided into the categories of time spent checking for process requests and time spent on storing and forwarding messages to and from the internal FIFO (**fifo\_check** and **fifo\_read\_write**, respectively). The pie chart can be customized by accessing **Main::Customize** menu. The available options in viewing the performance graph are as follows:

#### No Explode / Medium Explode / Heavy Explode

No Explode is a default option for viewing a pie chart, which differentiates the separate slices of the pie by color alone. Users can emphasize the separation between pie slices by selecting Medium or Heavy Explode, which, in addition to use of color, injects extra space between pie slices.

#### Quantifying CE Performance

The bus performance in terms of times spent on checking the internal FIFO and reading from and writing into the FIFO can be quantified with a ratio, their absolute values (in clock cycles), percentage values or with their respective labels.

#### Closing Performance Analysis Window

The pie chart window is closed by selecting **Main::Window**→**Close** menu.

## 4.7. Window Management

Window management deals with the management of Design Windows in the Workspace. Window management allows for closing, resizing, and arranging of multiple simultaneously opened Design Windows within the Workspace. Specifically, the tasks for window management are:

### Window Closing

Users can close the currently active Design Canvas in the Workspace by selecting **Main::Window→Close**. In addition, any of the Design Windows can be closed by clicking on a respective icon in the window's title bar.

Users can close all the currently opened Design Canvass in the Workspace by selecting **Main::Window→Close All**.

In all cases, closing a Design Canvas triggers a file closing action for the corresponding design file (see Section 4.2.5 *Design Closing* (page 37)).

### Window Arranging

Users can automatically arrange Design Canvass in the Workspace in a variety of manners. Selecting **Main::Window→Tile** will rearrange the Design Canvass in the Workspace in a tiled fashion. Selecting **Main::Window→Cascade** will rearrange the Design Canvass in the Workspace in a cascaded manner. Apart from that, windows can be freely resized and moved within the Workspace by dragging their title bar or borders. In addition, users can maximize and minimize Design Windows by clicking on a respective icon on the window's title bar.

### Window Switching

Selecting **Main::Window→Next** or **Main::Window→Previous** will switch the focus to and activate the next/previous Design Window in the list of opened windows. Using these actions, users can cycle through the list of windows. Design Windows are ordered in the window list according to the order in which they were opened. In addition, users can activate and raise any of the opened Design Windows by clicking into the window.

Finally, the bottom of the **Main::Window** menu contains entries for all currently opened Design Windows. Selecting any of these menu entries will activate and raise the corresponding Design Canvas.

### Window Toggling

Selecting `Main::Window→Project Manager` or `Main::Window→Output Window` will toggle (turn on and off) displaying of the Project Window and Output Window, respectively.

## Chapter 5. Data Modeling

### 5.1. Processing Element (PE) Data Model

PE Data Model characterizes the structure of PE and a memory sub-system. It consists of the following three data models: Datapath Model, Execution Model, and Memory Model.

**Table 5-1. Model**

Name	Sub-Models
ProcUnit	DPModel, ExecModel, MemModel

**Table 5-2. Attribute**

Name	Description	Value	Type	Source
type	Name for type of processing element	User defined Identifier	String	User define

#### 5.1.1. Datapath Model

Datapath model has a set of functional units and pipelines. It enumerates all the pipelines and functional units available in the PE. Multiple pipelines are allowed for superscalar architectures. This model is composed of a set of pipeline models and a set of functional unit models.

**Table 5-3. Model**

Name	Sub-Models
DPModel	FuncUnit, Pipeline

##### 5.1.1.1. Functional Unit Model

This model consists of type of a functional unit and its quantity in the PE. Delay for the functional unit is specified in operation model explained later.

**Table 5-4. Model**

Name	Sub-Models
FuncUnit	OperMode

**Table 5-5. Attribute**

Name	Description	Value	Type	Source
type	Name for type of functional unit	User defined Identifier	String	User define
quantity	Number of the functional units available in the PE	$\geq 1$	Int	Data sheet

**5.1.1.1.1. Operation Model**

Functional unit can operate in several modes. For each modes, it has different delays. For example, ALU may have addition and multiplication modes with different delays. In this model, delays for each operation modes are specified.

**Table 5-6. Model**

Name	Sub-Models
OperMode	

**Table 5-7. Attribute**

Name	Description	Value	Type	Source
mode	Name for type of mode	User defined Identifier	String	User define
oplat	Delay of functional unit for the operation mode	$\geq 1$	Int	Data sheet

### 5.1.1.2. Pipeline Model

Pipeline model consists of a name and a set of pipeline stages. It also defines branch delay model which is a statistical model that stores the branch prediction policy, cycles lost for mis-prediction and the average mis-prediction ratio. Please note that current version of ESE does not use branch prediction policy for now. This attribute will be used when ESE supports a dynamic branch prediction model.

**Table 5-8. Model**

Name	Sub-Models
Pipeline	Stage

**Table 5-9. Attribute**

Name	Description	Value	Type	Source
name	Identifier for the pipeline	User defined Identifier	String	User define
br_pred_policy	Branch prediction policy	TAKEN, NOT_TAKEN	String	User select
br_penalty	Cycle lost for mis-prediction	Number of cycles	Int	Data sheet on PE
br_pred_hit_ratio	Hit ratio from branch prediction	$\geq 0.00$ , $\leq 100.00$	FP	Simulation result by ISS or virtual platform

#### 5.1.1.2.1. Pipeline Stage Model

Pipeline stage model has a set of pointers to a functional unit that is available in that pipeline stage. It consists of a set of pointers to functional unit model. Please note that we can describe non-pipelined datapath by defining only 1 stage inside of pipeline model. For this, please refer to the example of custom hardware in an Appendix B.

**Table 5-10. Model**

Name	Sub-Models
------	------------



Name	Sub-Models
Stage	FURef

**Table 5-11. Attribute**

Name	Description	Value	Type	Source
name	Identifier for the pipeline stage	User defined Identifier	String	User define

#### 5.1.1.2.1.1. Pointer to Functional Unit Model.

Pointer to functional unit model consists of type of functional unit and number of available functional units in the pipeline stage.

**Table 5-12. Model**

Name	Sub-Models
FURef	

**Table 5-13. Attribute**

Name	Description	Value	Type	Source
type	Name for type of a functional unit	Type of a functional unit	String	Datapath model
quantity	Number of functional units available in the pipeline stage	$\geq 1, \leq$ the quantity of functional unit in Datapath model	Int	Datapath model

### 5.1.2. Execution Model

Execution model consists of a set of operation models and scheduling policy. Each operation model maps a operation to Datapath model and the scheduling policy decides the execution order for a given stream of operations.

**Table 5-14. Model**

Name	Sub-Models
ExecModel	Operation

**Table 5-15. Attribute**

Name	Description	Value	Type	Source
sched	Operation scheduling algorithm used by the PE such as ASAP, ALAP, List scheduling etc.	PIPELINE, LIST_SCHED	String	User select

#### 5.1.2.1. Operation Model

This model consists of the LLVM operations and their mapping to a pipelined datapath as defined in Datapath model. Please note that operation model uses LLVM operations instead of the specific set instruction sets or operations to make estimation framework re-targettable. LLVM operations can be easily mapped to the operations or instructions supported by the PE. To give an example, 'add', 'addc', 'addk' and 'addkc' instructions in the instruction set of MicroBlaze can be mapped to 'add' operation in LLVM instruction set. One LLVM operation can take care of several data types. Therefore, data type of variable for the operation should be also specified. Unless data type for the operation is not specified, no input or integer type is assumed.

The mapping of LLVM operation to a pipelined datapath consists of two steps. The first step is to map an operation to a set of pipeline stages and the second is to map available functional units to the pipeline stage. This mapping is done by two references, pipeline stage reference and functional unit reference explained later.

**Table 5-16. Model**

Name	Sub-Models
Operation	StgRef

**Table 5-17. Attribute**

Name	Description	Value	Type	Source
name	Name of LLVM instruction	LLVM instruction	String	A set of LLVM instruction
var_type	Type of operand for LLVM instruction	int, float, double	String	User select

#### 5.1.2.1.1. Pipeline Stage Reference

The pipeline stage reference consists of two flags and a pointer to a pipeline stage defined in Datapath model. Two flags are 'demand operand' and 'commit result' that specify the pipeline stages where the operation needs operand and commits the result, respectively.

**Table 5-18. Model**

Name	Sub-Models
StgRef	FURef

**Table 5-19. Attribute**

Name	Description	Value	Type	Source
name	Pointer to a pipeline stage	Name of a pipeline stage	String	Datapath model
flags	Specify 'demand operand' and 'commit result'	'COMMIT', 'DEMAND', 'COMMIT DEMAND'	String	User select

#### 5.1.2.1.1.1. Functional Unit Reference

Functional unit reference is used to associate a pipeline stage with functional units used

by operation in the pipeline stage. It specifies a type of functional unit along with its operation mode.

**Table 5-20. Model**

Name	Sub-Models
FURef	

**Table 5-21. Attribute**

Name	Description	Value	Type	Source
type	Pointer to a functional unit	Name of a functional unit	String	Datapath model
mode	Operation mode for a functional unit	Operation mode	String	Datapath model

### 5.1.3. Memory Model

Memory model defines cache model and external memory model. Current version of ESE can support one level cache in a memory sub-system.

**Table 5-22. Model**

Name	Sub-Models
MemModel	Cache, Memory

#### 5.1.3.1. Cache Model

Current cache model is a statistical model. The model specifies cache policy and its delay for an instruction cache and a data cache. It also defines average cache hit ratio for a set of cache sizes. Please note that cache policy is not used in current version of ESE now. This attribute will be used when ESE supports a dynamic cache model.

**Table 5-23. Model**

Name	Sub-Models
Cache	InstCache, DataCache

**Table 5-24. Attribute**

Name	Description	Value	Type	Source
policy	Cache policy	D-Mapped, 2way-Set	String	User select
i_cache_delay	Delay for an instruction cache	Number of cycles	Int	Data sheet
d_cache_delay	Delay for an data cache	Number of cycles	Int	Data sheet

#### 5.1.3.1.1. Instruction Cache Model

Instruction cache model defines cache hit ratio for a cache size.

**Table 5-25. Model**

Name	Sub-Models
InstCache	

**Table 5-26. Attribute**

Name	Description	Value	Type	Source
i_cache_size	Cache size for instruction cache	Cache size	Int	Data sheet
i_cache_hit_ratio	Cache hit ratio	$\geq 0.00, \leq 1.00$	FP	Simulation result by ISS or virtual platform

### 5.1.3.1.2. Data Cache Model

Data cache model defines cache hit ratio for a cache size.

**Table 5-27. Model**

Name	Sub-Models
DataCache	

**Table 5-28. Attribute**

Name	Description	Value	Type	Source
d_cache_size	Cache size for data cache	Cache size	Int	Data sheet
d_cache_hit_ratio	Cache hit ratio	$\geq 0.00, \leq 1.00$	FP	Simulation result by ISS or virtual platform

### 5.1.3.2. External Memory Model

The external memory latencies for memory read and memory write are specified here.

**Table 5-29. Model**

Name	Sub-Models
Memory	

**Table 5-30. Attribute**

Name	Description	Value	Type	Source
r_delay	The external memory access latency for read	Number of cycles	Int	Data sheet

Name	Description	Value	Type	Source
w_delay	The external memory access latency for write	Number of cycles	Int	Data sheet

## 5.2. Bus Model

The bus model defines the available features and delays that distinguish each protocol.

**Table 5-31. Attribute**

Name	Description	Value	Type
type	Bus protocol identifier	Name of a functional unit	String
address_bus_width	Width of the address bus	Width in bits	Integer
data_bus_width	Width of the data bus	Width in bits	Integer
max_number_masters	Maximum number of masters the bus allows	Number of masters	Integer
fcfs	First Come First Served arbitration policy	TRUE, FALSE	Bool
round_robin	Round Robin arbitration policy	TRUE, FALSE	Bool
priority	Priority arbitration policy	TRUE, FALSE	Bool
least_freq_used	Least Frequently Used arbitration policy	TRUE, FALSE	Bool

Name	Description	Value	Type
arbitration_pipelining	Support for Arbitration pipelined with Address phase	TRUE, FALSE	Bool
arb_req_delay	Arbitration Request delay	$\geq 1$	Integer
default_master	If a PE is a default master (bus parking)	TRUE, FALSE	Bool
split_transactions	Support for Split transactions	TRUE, FALSE	Bool
retry	Support for RETRY operations	TRUE, FALSE	Bool
retry_cycles	Number of cycles before a PE retries	$\geq 1$	Integer
timeout	Support for Timeout if a PE does not respond	TRUE, FALSE	Bool
timeout_cycles	Number of cycles before a Timeout is called	$\geq 1$	Integer
preemption	Support for process preemption	TRUE, FALSE	Bool
master_abort	Support for Abort	TRUE, FALSE	Bool
bus_lock	Support for locking a bus to a PE	TRUE, FALSE	Bool
burst_mode	Support for burst mode data transfer	TRUE, FALSE	Bool
burst_mode_length	Length in cycles of the burst	$\geq 1$	Integer
control_phase	Presence of a control phase before address/data phase	TRUE, FALSE	Bool



<b>Name</b>	<b>Description</b>	<b>Value</b>	<b>Type</b>
control_phase_length	Length of the control phase in cycles	$\geq 1$	Integer
address_data_pipelining	Support for pipelining between address and data phases	TRUE, FALSE	Bool

## Appendix A. XML stylesheet for PE Data Model

This appendix contains a full XML stylesheet for PE Data Model.

### A.1. Data Type

```
<xs:simpleType name="IdentName">
  <xs:restriction base="xs:string">
    <xs:pattern value="_*[a-zA-Z][a-zA-Z0-9_]*"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="IdentNameList">
  <xs:list itemType="IdentName"/>
</xs:simpleType>
```

### A.2. Elements

```
<xs:complexType name="ProcUnitModel">
  <xs:attribute name="version" type="xs:string" use="required"/>

  <xs:element name="procunit" type="ProcUnit" minOccurs="1" maxOccurs="unbounded">
    <xs:complexType>
      <xs:attribute name="type" type="xs:string"/>

      <xs:element name="execmodel" type="ExecModel" minOccurs="1" maxOccurs="unbounded"/>
      <xs:element name="memmodel" type="MemModel" minOccurs="1" maxOccurs="unbounded"/>
      <xs:element name="dpmodel" type="DPModel" minOccurs="1" maxOccurs="unbounded"/>
    </xs:complexType>
  </xs:element>

</xs:complexType>

<xs:complexType name="ExecModel">
```

```
<xs:attribute name="sched" type="IdentName" use="required"/>

<xs:element name="operation" type="Operation" minOccurs="1" maxOccurs="unbounded">
  <xs:complexType>
    <xs:attribute name="name" type="IdentName" use="required"/>
    <xs:attribute name="var_type" type="IdentName" use="required"/>

    <xs:element name="stgref" type="StgRef" minOccurs="1" maxOccurs="unbounded">
      <xs:complexType>
        <xs:attribute name="name" type="IdentName" use="required"/>
        <xs:attribute name="flags" use="required">
          <xs:simpleType>
            <xs:restriction base="xs:string">
              <xs:enumeration value="COMMIT"/>
              <xs:enumeration value="DEMAND"/>
              <xs:enumeration value="DEMAND COMMIT"/>
            </xs:restriction>
          </xs:simpleType>
        </xs:attribute>

        <xs:element name="furef" type="FURef" minOccurs="1" maxOccurs="unbounded"/>
      </xs:complexType>
    </xs:element>
  </xs:complexType>
</xs:element>

<xs:complexType name="FURef">
  <xs:attribute name="type" type="IdentName" use="required"/>
  <xs:attribute name="quantity" type="IdentName" use="required"/>
  <xs:attribute name="mode" type="IdentName" use="required"/>
</xs:complexType>

<xs:complexType name="MemModel">
  <xs:element name="cache" type="Cache" minOccurs="0" maxOccurs="unbounded">
    <xs:complexType>
      <xs:attribute name="policy" type="IdentName" use="required"/>
    </xs:complexType>
  </xs:element>
</xs:complexType>
```

```
<!-- below is for cache which has distinction btn i cache and d cache -->
<xs:attribute name="i_cache_delay" type="xs:int"/>
<xs:attribute name="d_cache_delay" type="xs:int"/>

<!-- below is for cache which has no distinction btn i cache and d cache -->
<xs:attribute name="delay" type="xs:string"/>
<xs:attribute name="cache_size" type="xs:string"/>
<xs:attribute name="i_cache_ratio" type="xs:float"/>
<xs:attribute name="d_cache_ratio" type="xs:float"/>

<xs:element name="InstCache" type="InstCache" minOccurs="0" maxOccurs="unbounded">
  <xs:attribute name="i_cache_size" type="xs:string" use="required"/>
  <xs:attribute name="i_cache_ratio" type="xs:float" use="required"/>
</xs:element>
<xs:element name="DataCache" type="DataCache" minOccurs="0" maxOccurs="unbounded">
  <xs:attribute name="d_cache_size" type="xs:string" use="required"/>
  <xs:attribute name="d_cache_ratio" type="xs:float" use="required"/>
</xs:element>
</xs:complexType>
</xs:element>
<xs:element name="memory" type="Memory" minOccurs="1" maxOccurs="unbounded">
  <xs:complexType>
    <xs:attribute name="w_delay" type="xs:int" use="required"/>
    <xs:attribute name="r_delay" type="xs:int" use="required"/>
  </xs:complexType>
</xs:element>
</xs:complexType>

<xs:complexType name="DPModel">
  <xs:element name="pipeline" type="Pipeline" minOccurs="1" maxOccurs="unbounded">
    <xs:complexType>
      <xs:attribute name="name" type="IdentName" use="required"/>
      <xs:attribute name="br_pred_policy" type="IdentName" use="required"/>
      <xs:simpleType>
        <xs:restriction base="xs:string">
          <xs:enumeration value="TAKEN"/>
          <xs:enumeration value="NOT_TAKEN"/>
        </xs:restriction>
      </xs:simpleType>
    </xs:complexType>
  </xs:element>
</xs:complexType>
```

```
</xs:simpleType>
</xs:attribute>
<xs:attribute name="br_pred_hit_ratio" type="xs:float" use="required"/>
<xs:attribute name="br_penalty" type="xs:int" use="required"/>

<xs:element name="stage" type="Stage" minOccurs="1" maxOccurs="unbounded">
  <xs:complexType>
    <xs:attribute name="name" type="IdentName" use="required"/>

    <xs:element name="furef" type="FURef" minOccurs="1" maxOccurs="unbounded"/>
    </xs:complexType>
  </xs:element>
</xs:complexType>
</xs:element>

<xs:element name="funcunit" type="FuncUnit" minOccurs="1" maxOccurs="unbounded">
  <xs:complexType>
    <xs:attribute name="type" type="IdentName" use="required"/>
    <xs:attribute name="quantity" type="xs:int" use="required"/>

    <xs:element name="opermode" type="OperMode" minOccurs="1" maxOccurs="unbounded">
      <xs:complexType>
        <xs:attribute name="mode" type="IdentName" use="required"/>
        <xs:attribute name="oplat" type="xs:int" use="required"/>
      </xs:complexType>
    </xs:element>
  </xs:complexType>
</xs:element>
</xs:complexType>
```

## Appendix B. XML stylesheet for Bus Models

```
<xs:complexType name="BUS">
  <xs:attribute name="type" type="IdentName"/>
  <xs:attribute name="address_bus_width" type="xs:int"/>
  <xs:attribute name="data_bus_width" type="xs:int"/>
  <xs:attribute name="max_number_masters" type="xs:int"/>
  <xs:attribute name="fcfs" type="xs:bool"/>
  <xs:attribute name="round_robin" type="xs:bool"/>
  <xs:attribute name="priority" type="xs:bool"/>
  <xs:attribute name="least_freq_used" type="xs:bool"/>
  <xs:attribute name="arbitration_pipelining" type="xs:bool"/>
  <xs:attribute name="arb_req_delay" type="xs:int"/>
  <xs:attribute name="default_master" type="xs:bool"/>
  <xs:attribute name="split_transactions" type="xs:bool"/>
  <xs:attribute name="retry" type="xs:bool"/>
  <xs:attribute name="retry_cycles" type="xs:int"/>
  <xs:attribute name="timeout" type="xs:bool"/>
  <xs:attribute name="timeout_cycles" type="xs:int"/>
  <xs:attribute name="preemption" type="xs:bool"/>
  <xs:attribute name="master_abort" type="xs:bool"/>
  <xs:attribute name="bus_lock" type="xs:bool"/>
  <xs:attribute name="burst_mode" type="xs:bool"/>
  <xs:attribute name="burst_mode_length" type="xs:int"/>
  <xs:attribute name="control_phase" type="xs:bool"/>
  <xs:attribute name="control_phase_length" type="xs:int"/>
  <xs:attribute name="address_data_pipelining" type="xs:bool"/>
</xs:complexType>
```

## Appendix C. Example XMLs

This appendix contains a full XML stylesheet for PE Data Model.

### C.1. Example XML for MicroBlaze

```
<ProcUnitModel version = "0.0.1">
  <ProcUnit type="MICROBLAZE">
    <ExecModel sched="PIPELINE">
      <Operation name="ret">
        <StgRef name = "IF">
          <FURef type = "InstFetch" mode = "DEFAULT"/>
        </StgRef>
        <StgRef name = "ID" flags="DEMAND">
          <FURef type = "InstDecode" mode = "DEFAULT"/>
        </StgRef>
        <StgRef name = "EX" flags="COMMIT">
          <FURef type="reg" mode="RdReg"/>
        </StgRef>
      </Operation>
      <Operation name="malloc"> <!-- allocate memory from system heap -->
        <StgRef name = "IF">
          <FURef type = "InstFetch" mode = "DEFAULT"/>
        </StgRef>
        <StgRef name = "ID" flags="DEMAND">
          <FURef type = "InstDecode" mode = "DEFAULT"/>
        </StgRef>
        <StgRef name = "EX" flags="COMMIT">
          <FURef type="reg" mode="WrReg"/>
        </StgRef>
      </Operation>
      <Operation name="free"> <!-- returns memory back to system heap -->
        <StgRef name = "IF">
          <FURef type = "InstFetch" mode = "DEFAULT"/>
        </StgRef>
        <StgRef name = "ID" flags="DEMAND">
          <FURef type = "InstDecode" mode = "DEFAULT"/>
        </StgRef>
```

```

    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type="reg" mode="WrReg"/>
    </StgRef>
</Operation>
<Operation name="alloca"> <!-- allocate memory from current stack frame -->
    <StgRef name = "IF">
        <FURef type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags = "DEMAND">
        <FURef type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type="reg" mode="WrReg"/>
    </StgRef>
</Operation>
<Operation name="load"> <!-- read from memory -->
    <StgRef name = "IF">
        <FURef type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags = "DEMAND">
        <FURef type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type="mem-Port" mode="RdPort"/>
    </StgRef>
</Operation>
<Operation name="store"> <!-- write to memory -->
    <StgRef name = "IF">
        <FURef type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags = "DEMAND">
        <FURef type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type="mem-Port" mode="WrPort"/>
    </StgRef>
</Operation>

```



```
<Operation name="call"> <!-- function call -->
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="reg" mode="RdReg"/>
  </StgRef>
</Operation>

<Operation name="br">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="add" var_type="int">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="add" var_type="float">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
```

```
<StgRef name = "ID" flags ="DEMAND">
  <FURef type = "InstDecode" mode = "DEFAULT"/>
</StgRef>
<StgRef name = "EX" flags ="COMMIT">
  <FURef type="FP-ALU" mode="FPAdd"/>
</StgRef>
</Operation>
<Operation name="sub" var_type="int">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="sub" var_type="float">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="FP-ALU" mode="FPAdd"/>
  </StgRef>
</Operation>
<Operation name="mul" var_type="int">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-Mult/Div" mode="IntMult"/>
  </StgRef>
</Operation>
```

```
</StgRef>
</Operation>
<Operation name="mul" var_type="float">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="FP-Mult/Div" mode="FPMult"/>
  </StgRef>
</Operation>
<Operation name="udiv">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-Mult/Div" mode="IntDiv"/>
  </StgRef>
</Operation>
<Operation name="sdiv">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-Mult/Div" mode="IntDiv"/>
  </StgRef>
</Operation>
<Operation name="fdiv">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
```

```
</StgRef>
<StgRef name = "ID" flags = "DEMAND">
  <FURef type = "InstDecode" mode = "DEFAULT"/>
</StgRef>
<StgRef name = "EX" flags = "COMMIT">
  <FURef type = "FP-Mult/Div" mode = "FPDiv"/>
</StgRef>
</Operation>
<Operation name = "urem"> <!-- returns remainder of a division -->
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags = "DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags = "COMMIT">
    <FURef type = "int-Mult/Div" mode = "IntDiv"/>
  </StgRef>
</Operation>
<Operation name = "srem">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags = "DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags = "COMMIT">
    <FURef type = "int-Mult/Div" mode = "IntDiv"/>
  </StgRef>
</Operation>
<Operation name = "frem">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags = "DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags = "COMMIT">
```

```

        <FUPref type="FP-Mult/Div" mode="FPDiv"/>
    </StgRef>
</Operation>
<Operation name="shl"> <!-- shift -->
    <StgRef name = "IF">
        <FUPref type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags="DEMAND">
        <FUPref type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags="COMMIT">
        <FUPref type="int-ALU" mode="IntALU"/>
    </StgRef>
</Operation>
<Operation name="shr"> <!-- shift -->
    <StgRef name = "IF">
        <FUPref type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags="DEMAND">
        <FUPref type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags="COMMIT">
        <FUPref type="int-ALU" mode="IntALU"/>
    </StgRef>
</Operation>
<Operation name="lshr"> <!-- logical shift -->
    <StgRef name = "IF">
        <FUPref type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags="DEMAND">
        <FUPref type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags="COMMIT">
        <FUPref type="int-ALU" mode="IntALU"/>
    </StgRef>
</Operation>
<Operation name="ashr"> <!-- arithmetic shift -->
    <StgRef name = "IF">

```

```
<FURef type = "InstFetch" mode = "DEFAULT"/>
</StgRef>
<StgRef name = "ID" flags = "DEMAND">
  <FURef type = "InstDecode" mode = "DEFAULT"/>
</StgRef>
<StgRef name = "EX" flags = "COMMIT">
  <FURef type="int-ALU" mode="IntALU"/>
</StgRef>
</Operation>
<Operation name="and">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags = "DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags = "COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="or">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags = "DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags = "COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="xor">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags = "DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
```

```
<StgRef name = "EX" flags ="COMMIT">
  <FURef type="int-ALU" mode="IntALU"/>
</StgRef>
</Operation>
<Operation name="fptoui">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="FP-ALU" mode="FPCvt"/>
  </StgRef>
</Operation>
<Operation name="fptosi">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="FP-ALU" mode="FPCvt"/>
  </StgRef>
</Operation>
<Operation name="uitofp">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="FP-ALU" mode="FPCvt"/>
  </StgRef>
</Operation>
<Operation name="sitofp">
```

```
<StgRef name = "IF">
  <FURef type = "InstFetch" mode = "DEFAULT"/>
</StgRef>
<StgRef name = "ID" flags = "DEMAND">
  <FURef type = "InstDecode" mode = "DEFAULT"/>
</StgRef>
<StgRef name = "EX" flags = "COMMIT">
  <FURef type = "FP-ALU" mode = "FPCvt"/>
</StgRef>
</Operation>
<Operation name = "icmp">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags = "DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags = "COMMIT">
    <FURef type = "int-ALU" mode = "IntALU"/>
  </StgRef>
</Operation>
<Operation name = "fcmp">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags = "DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags = "COMMIT">
    <FURef type = "FP-ALU" mode = "FPCmp"/>
  </StgRef>
</Operation>
<Operation name = "seteq">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags = "DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
```



```
</StgRef>
<StgRef name = "EX" flags ="COMMIT">
  <FURef type="int-ALU" mode="IntALU"/>
</StgRef>
</Operation>
<Operation name="setne">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="setle">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="setge">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
```

```
<Operation name="setlt">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="setgt">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="cast" var_type="int">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="cast" var_type="float">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags="DEMAND">
```

```

        <FURef type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type="FP-ALU" mode="FPCvt"/>
    </StgRef>
</Operation>
<Operation name="cast" var_type="double">
    <StgRef name = "IF">
        <FURef type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags = "DEMAND">
        <FURef type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type="FP-ALU" mode="FPCvt"/>
    </StgRef>
</Operation>

<Operation name="getelementptr">
    <StgRef name = "IF">
        <FURef type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags = "DEMAND">
        <FURef type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type="int-ALU" mode="IntALU"/>
    </StgRef>
</Operation>
<Operation name="phi">
    <StgRef name = "IF">
        <FURef type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags = "DEMAND">
        <FURef type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type="int-ALU" mode="IntALU"/>

```

```
</StgRef>
</Operation>
<Operation name="unreachable">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="invoke">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="unwind">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "ID" flags ="DEMAND">
    <FURef type = "InstDecode" mode = "DEFAULT"/>
  </StgRef>
  <StgRef name = "EX" flags ="COMMIT">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="switch">
  <StgRef name = "IF">
    <FURef type = "InstFetch" mode = "DEFAULT"/>
```

```

    </StgRef>
    <StgRef name = "ID" flags = "DEMAND">
        <FURef type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type = "int-ALU" mode = "IntALU"/>
    </StgRef>
</Operation>
<Operation name = "select">
    <StgRef name = "IF">
        <FURef type = "InstFetch" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "ID" flags = "DEMAND">
        <FURef type = "InstDecode" mode = "DEFAULT"/>
    </StgRef>
    <StgRef name = "EX" flags = "COMMIT">
        <FURef type = "int-ALU" mode = "IntALU"/>
    </StgRef>
</Operation>
</ExecModel>

<MemModel>
    <Cache policy = "D-Mapped" i_cache_delay = "1" d_cache_delay = "1">
        <InstCache i_cache_size = "1K" i_cache_ratio = "0.6614"/>
        <InstCache i_cache_size = "2K" i_cache_ratio = "0.7917"/>
        <InstCache i_cache_size = "4K" i_cache_ratio = "0.8606"/>
        <InstCache i_cache_size = "8K" i_cache_ratio = "0.9503"/>
        <InstCache i_cache_size = "16K" i_cache_ratio = "0.9779"/>
        <InstCache i_cache_size = "32K" i_cache_ratio = "0.9805"/>
        <InstCache i_cache_size = "64K" i_cache_ratio = "0.9817"/>
        <DataCache d_cache_size = "2K" d_cache_ratio = "0.6379"/>
        <DataCache d_cache_size = "4K" d_cache_ratio = "0.6661"/>
        <DataCache d_cache_size = "8K" d_cache_ratio = "0.6714"/>
        <DataCache d_cache_size = "16K" d_cache_ratio = "0.6996"/>
        <DataCache d_cache_size = "32K" d_cache_ratio = "0.6996"/>
        <DataCache d_cache_size = "64K" d_cache_ratio = "0.6996"/>
    </Cache>
    <Memory r_delay = "8" w_delay = "3"/>

```

</MemModel>

<DPMModel>

<Pipeline name = "default" br\_pred\_policy = "TAKEN" br\_pred\_hit\_ratio = "60.00" br\_penalty = "2">

<Stage name = "IF">

<FURef type = "InstFetch" quantity = "1"/>

</Stage>

<Stage name = "ID">

<FURef type = "InstDecode" quantity = "1"/>

</Stage>

<Stage name = "EX">

<FURef type = "reg" quantity = "32"/>

<FURef type = "mem-Port" quantity = "1"/>

<FURef type = "int-ALU" quantity = "1"/>

<FURef type = "int-Mult/Div" quantity = "1"/>

<FURef type = "FP-ALU" quantity = "1"/>

<FURef type = "FP-Mult/Div" quantity = "1"/>

</Stage>

</Pipeline>

<FuncUnit type="InstFetch" quantity="1">

<OperMode mode="DEFAULT" oplat="1"/>

</FuncUnit>

<FuncUnit type="InstDecode" quantity="1">

<OperMode mode="DEFAULT" oplat="1"/>

</FuncUnit>

<FuncUnit type="reg" quantity="32">

<OperMode mode="RdReg" oplat="1"/>

<OperMode mode="WrReg" oplat="1"/>

</FuncUnit>

<FuncUnit type="mem-Port" quantity="1">

<OperMode mode="RdPort" oplat="2"/>

<OperMode mode="WrPort" oplat="1"/>

</FuncUnit>

<FuncUnit type="int-ALU" quantity="1">

<OperMode mode="IntALU" oplat="1"/>

</FuncUnit>

<FuncUnit type="int-Mult/Div" quantity="1">

<OperMode mode="IntMult" oplat="3"/>

```

    <OperMode mode="IntDiv" oplat="34"/>
  </FuncUnit>
  <FuncUnit type="FP-ALU" quantity="1">
    <OperMode mode="FPAdd" oplat="6"/>
    <OperMode mode="FPCmp" oplat="3"/>
    <OperMode mode="FPCvt" oplat="3"/>
  </FuncUnit>
  <FuncUnit type="FP-Mult/Div" quantity="1">
    <OperMode mode="FPMult" oplat="6"/>
    <OperMode mode="FPDiv" oplat="30"/>
    <OperMode mode="FPSqrt" oplat="6"/>
  </FuncUnit>

</DPMModel>
</ProcUnit>
</ProcUnitModel>

```

## C.2. Example XML for Custom Hardware

```

<ProcUnitModel version = "0.0.1">
  <ProcUnit type="DCT32">
    <ExecModel sched="LIST_SCHED">
      <Operation name="ret">
        <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
          <FURef type="reg" mode="RdReg"/>
        </StgRef>
      </Operation>
      <Operation name="malloc"> <!-- allocate memory from system heap -->
        <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
          <FURef type="reg" mode="WrReg"/>
        </StgRef>
      </Operation>
      <Operation name="free"> <!-- returns memory back to system heap -->
        <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
          <FURef type="reg" mode="WrReg"/>
        </StgRef>
      </Operation>
    </ExecModel>
  </ProcUnit>
</ProcUnitModel>

```

```

    </StgRef>
  </Operation>
  <Operation name="alloca"> <!-- allocate memory from current stack frame -->
    <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
      <FURef type="reg" mode="WrReg"/>
    </StgRef>
  </Operation>
  <Operation name="load"> <!-- read from memory -->
    <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
      <FURef type="mem-Port" mode="RdPort"/>
    </StgRef>
  </Operation>
  <Operation name="store"> <!-- write to memory -->
    <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
      <FURef type="mem-Port" mode="WrPort"/>
    </StgRef>
  </Operation>
  <Operation name="call"> <!-- function call -->
    <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
      <FURef type="reg" mode="RdReg"/>
    </StgRef>
  </Operation>

  <Operation name="br">
    <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
      <FURef type="int-ALU" mode="IntALU"/>
    </StgRef>
  </Operation>
  <Operation name="add" var_type="int">
    <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
      <FURef type="int-ALU" mode="IntALU"/>
    </StgRef>
  </Operation>
  <Operation name="add" var_type="float">
    <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
      <FURef type="FP-ALU" mode="FPAdd"/>
    </StgRef>
  </Operation>

```



```
<Operation name="sub" var_type="int">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="sub" var_type="float">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="FP-ALU" mode="FPAdd"/>
  </StgRef>
</Operation>
<Operation name="mul" var_type="int">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-Mult/Div" mode="IntMult"/>
  </StgRef>
</Operation>
<Operation name="mul" var_type="float">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="FP-Mult/Div" mode="FPMult"/>
  </StgRef>
</Operation>
<Operation name="udiv">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-Mult/Div" mode="IntDiv"/>
  </StgRef>
</Operation>
<Operation name="sdiv">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-Mult/Div" mode="IntDiv"/>
  </StgRef>
</Operation>
<Operation name="fdiv">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="FP-Mult/Div" mode="FPDiv"/>
  </StgRef>
</Operation>
<Operation name="urem"> <!-- returns remainder of a division -->
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-Mult/Div" mode="IntDiv"/>
  </StgRef>
</Operation>
```

```
</StgRef>
</Operation>
<Operation name="srem">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-Mult/Div" mode="IntDiv"/>
  </StgRef>
</Operation>
<Operation name="frem">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="FP-Mult/Div" mode="FPDiv"/>
  </StgRef>
</Operation>
<Operation name="shl"> <!-- shift -->
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="shr"> <!-- shift -->
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="lshr"> <!-- logical shift -->
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="logic-SHIFT" mode="shift"/>
  </StgRef>
</Operation>
<Operation name="ashr"> <!-- arithmetic shift -->
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="and">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="or">
```

```
<StgRef name = "SINGLE" flags = "COMMIT DEMAND">
  <FURef type="int-ALU" mode="IntALU"/>
</StgRef>
</Operation>
<Operation name="xor">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="fptoui">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="FP-ALU" mode="FPCvt"/>
  </StgRef>
</Operation>
<Operation name="fptosi">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="FP-ALU" mode="FPCvt"/>
  </StgRef>
</Operation>
<Operation name="uitofp">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="FP-ALU" mode="FPCvt"/>
  </StgRef>
</Operation>
<Operation name="sitofp">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="FP-ALU" mode="FPCvt"/>
  </StgRef>
</Operation>
<Operation name="icmp">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="fcmp">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="FP-ALU" mode="FPCmp"/>
  </StgRef>
```

```
</Operation>
<Operation name="seteq">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="setne">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="setle">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="setge">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="setlt">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="setgt">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="cast" var_type="int">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FURef type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="cast" var_type="float">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
```

```
<FUPref type="FP-ALU" mode="FPCvt"/>
</StgRef>
</Operation>

<Operation name="getelementptr">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FUPref type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="phi">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FUPref type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="unreachable">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FUPref type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="invoke">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FUPref type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="unwind">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FUPref type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="switch">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FUPref type="int-ALU" mode="IntALU"/>
  </StgRef>
</Operation>
<Operation name="select">
  <StgRef name = "SINGLE" flags = "COMMIT DEMAND">
    <FUPref type="int-ALU" mode="IntALU"/>
  </StgRef>
```

```

</Operation>
</ExecModel>
<DPMModel>
<Pipeline name = "default" br_pred_policy = "TAKEN" br_pred_hit_ratio = "100.00" br_penalty = "0">
  <Stage name = "SINGLE">
    <FURef type = "reg" quantity = "32"/>
    <FURef type = "mem-Port" quantity = "1"/>
    <FURef type = "int-ALU" quantity = "1"/>
    <FURef type = "int-Mult/Div" quantity = "1"/>
    <FURef type = "logic-SHIFT" quantity = "3"/>
    <FURef type = "FP-ALU" quantity = "1"/>
    <FURef type = "FP-Mult/Div" quantity = "1"/>
  </Stage>
</Pipeline>
<FuncUnit type="reg" quantity="32">
  <OperMode mode="RdReg" oplat="1"/>
  <OperMode mode="WrReg" oplat="1"/>
</FuncUnit>
<FuncUnit type="mem-Port" quantity="1">
  <OperMode mode="RdPort" oplat="1"/>
  <OperMode mode="WrPort" oplat="1"/>
</FuncUnit>
<FuncUnit type="int-ALU" quantity="1">
  <OperMode mode="IntALU" oplat="1"/>
</FuncUnit>
<FuncUnit type="int-Mult/Div" quantity="1">
  <OperMode mode="IntMult" oplat="3"/>
  <OperMode mode="IntDiv" oplat="20"/>
</FuncUnit>
<FuncUnit type="logic-SHIFT" quantity="3">
  <OperMode mode="shift" oplat="1"/>
</FuncUnit>
<FuncUnit type="FP-ALU" quantity="1">
  <OperMode mode="FPAdd" oplat="2"/>
  <OperMode mode="FPCmp" oplat="2"/>
  <OperMode mode="FPCvt" oplat="2"/>
</FuncUnit>
<FuncUnit type="FP-Mult/Div" quantity="1">

```

```
<OperMode mode="FPMult" oplat="4"/>
<OperMode mode="FPDiv" oplat="12"/>
<OperMode mode="FPSqrt" oplat="24"/>
</FuncUnit>
</DPMModel>

</ProcUnit>
</ProcUnitModel>
```

### C.3. Example XML for OPB

```
<BUS data_bus_width = "32"
  arb_req_delay = "1"
  arbitration_pipelining = "true"
  address_data_pipelining = "true"
  address_bus_width = "32"
  default_master = "true"
  bus_lock = "true"
  split_transactions = "false"
  retry = "true"
  retry_cycles = "1"
  timeout = "true"
  timeout_cycles = "16"
  preemption = "true"
  burst_mode = "true"
  burst_mode_length = "240"
  fcfs = "true"
  round_robin = "true"
  priority = "true"
  least_freq_used = "true"/>
```