

Reform of Experimental Teaching in FPGA Technology Based on OBE Concept

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ABSTRACT With China becoming a formal member of the *Washington Accord* in 2016, the international influence of the engineering education in China has grown rapidly in recent years. As one of the core concepts in the accredited system of the higher engineering education, the Outcome-Based Education (OBE) is an advanced educational idea which can provide more efficient method for ability training in the teaching process. In order to overcome the shortcoming of traditional FPGA experimental teaching, a series of experimental cases, which correspond to the training of different abilities, have been designed systematically for the course named FPGA Technology based on OBE concept. Good effect has been obtained by the reform of relevant experimental teaching.

1. INTRODUCTION

On June 2, 2016, China became a formal member of the *Washington Accord* [1] which was a well-known international agreement between bodies responsible for accrediting engineering degree programmes [2]. It meant that the internationalization process of the engineering education in China was officially started, and the mutual recognition of engineering qualifications could be realized between the participating countries by a multi-lateral agreement. The accredited system of the higher engineering education contains three core concepts: Students-Centered, Outcome-Based Education, and Continuous-Quality Improvement [3]. Among above three concepts, the Outcome-Based Education (OBE) [4] is a kind of advanced educational idea which regards the final learning outcomes of students as the important target of teaching design. Here learning outcomes represent a kind of ability which is trained by the course teaching, and meanwhile the clear mapping relation between the course contents and the different aspects of ability also need to be established.

On the other hand, FPGA (Field-Programmable Gate Array), which is a type of significant programmable logic device, has been looked upon as a powerful tool for the design of digital systems with the development of VLSI (Very Large Scale Integration) technology [5]. At present, the design and developing technology of FPGA has been an important supplementary means for high-speed digital signal processing and artificial intelligence application. Therefore, the course named FPGA Technology was set for the Communication Engineering speciality in Chengdu University of Information technology (CUIT) to adapt to the development of electronic information technology. Considering of the obvious engineering characteristics that half of the teaching period of this course is occupied by experiments, it is meaningful to combine the experimental teaching reform with the advanced OBE concept to meet the requirement of international engineering education.

2. TRADITIONAL FPGA EXPERIMENTAL TEACHING

The remarkable features of traditional experimental teaching in FPGA-related courses can be summarized to four aspects: firstly, each experimental case is designed around a certain knowledge point, and the correlation degree between different experiments is relatively low. Secondly, fulfilling the intended function is emphasized in the traditional experimental, but the target of

ability training is not clearly set in the process of the experimental teaching. Thirdly, the types of experiments are few, and the design of experimental content also lacks of hierarchy. Finally, the evaluation mode is simple and incomplete, and hard to provide an effective conclusion for the improvement of teaching process.

3. Design of Experimental Cases With OBE Concept

In order to overcome the shortcoming of traditional FPGA experimental teaching, a series of experimental cases, which cover different types and correspond to the training of different abilities, have been designed systematically based on OBE concept. As shown in Table 1, five experiments are divided into several types such as learning of different tools, basic module design, and complicated module design according to experimental targets, degree of difficulty, and characteristics of relevant abilities [6]. From Exp.1 to Exp.5, the teaching contents have a variation from simple to complex [7], while the training of relevant ability is designed from basic to systemic.

Table 1 Design of experiments in FPGA Technology course based on OBE concept

Experiments	Types	Abilities
1. Using Altera DE2 board	Learning hardware tool	Application of FPGA device
2. Schematic design	Learning software tool	Grasping Schematic design method in the Quartus II software
3. Controlling the 7-segment displays by switches	Learning software tool+ Basic module design	Grasping Verilog design method in the Quartus II software. Realization of the simple combinational logic function using Verilog design.
4. Counters and Frequency dividers	Basic module design	Realization of the simple sequential logic function using Verilog design.
5. Flow visualization of a number	Complicated module design	Realization of the complicated sequential logic function using Verilog design.

3.1. Outline of Experiments

A brief introduction is provided for each experiment as follow:

3.1.1. Experiment 1

The main content of Exp.1 is familiar with the structure and basic function of Altera DE2 board, and recognizing the important components on the board which can constitute the minimum FPGA system. In addition, the ability how to use the software DE2 control panel to control or test the board is also requisite. In short, DE2 board is a basic hardware tool for FPGA development, and grasping the usage of DE2 hardware platform is a basic ability for the subsequent experiments.

3.1.2. Experiment 2

Exp.2 is using the schematic design method in the Quartus II software to realize a simple combinational logic function that controls a single light from different switches. The Quartus II system includes full support for many popular methods of entering a description of the desired circuit into a CAD (Computer Aided Design) system. Here a typical FPGA CAD flow can be practiced by this basic case to help students to grasp relevant operations such as Schematic Design Entry, Simulating the Designed Circuit, and so on. Further, the completed design file will be loaded on the DE2 board to observe the final result. Hence the ability of using FPGA device trained in Exp.1 can be strengthened in Exp.2.

3.1.3. Experiment 3

Exp.3 contains two important parts: learning the Verilog design method and design of a basic combinational logic module. At first, the Verilog design method is also practiced in the Quartus II system and takes the similar FPGA CAD flow compared with the schematic design method. The main differences between above two design methods are just the type of project file and the simulation method, respectively. Specifically, the Verilog HDL file is used for the Verilog design method to establish a project while the Block Diagram/ Schematic file is used for the schematic

design. On the other hand, a Testbench is need to be written before simulating in the Verilog design, but a vector waveform file is requisite for simulation in the schematic design. Hence the practice of schematic design in Exp.2 lays a good foundation for the learning of the Verilog design. Second, the experimental module is considered to combine the number display with the design of decoder, and the teaching process can be separated into two steps. For the first step, showing a decimal number on a 7-segment display need to provide a correct binary number which corresponds to the right display result (every segment is on or off in the right order) on a nixie tube. It is a kind of simple training of combinational logic design using Verilog description. For the second step, various combinations of three switches are set to control eight 7-segment displays to realize a number appearing in different position. It can be regarded as a 3-8 decoder which shows more complicated combinational logic function. The above two steps of teaching process are helpful for students to have a clear idea in the design of combinational logic module using Verilog design method.

3.1.4. Experiment 4

Two basic sequential logic modules, counter and frequency divider, are arranged in Exp.4 in order to do some preparation for the design of complicated sequential logic module. Here the ability that uses Verilog HDL to describe the basic function of counter and frequency divider, and the ability that writes the Testbench to test above two function modules are two core targets for students to achieve. The Verilog description of the counter is strongly related to that of the frequency divider. In other words, how to describe a counter using Verilog HDL is a significant part to realize the function of the frequency divider. More specifically, a 8-bit BCD (binary-coded-decimal) counter with several design conditions are provided for students to be familiar with the define method and test technology for the simple sequential logic module, and on this basis a frequency divider module need to be completed using at least two methods that have been taught in the theory course.

3.1.5. Experiment 5

Exp.5 is a comprehensive design experiment that aim to realize the flow visualization of a number. To accomplish this case, several abilities such as using hardware and software tools, having a good command of different design methods in the Quartus II system, and grasping the Verilog description of combinational logic circuit and sequential logic circuit, need to be formed in the experimental teaching process from Exp.1 to Exp.4. The function module of this experiment is consisted of four parts: the display module, the counter module, the flow control module (containing the frequency dividing function), and the reset module.

3.2. Relation between Abilities and Experiments

To accurately reflect the OBE educational idea in the experimental teaching process, there is a clear mapping relation presented between experimental contents and different abilities, as shown in Figure 1. Firstly, the final learning outcomes of the experimental teaching in FPGA Technology is set as advanced FPGA design ability for the complicated digital logic function. In order to support the final target, two kinds of ability are defined as using tools and complicated sequential logic design, respectively.

Secondly, the tools can be divided into two groups: hardware tool (DE2 board) and software tool (Quartus II system). The ability of using hardware tool is supported by the Exp.1 while the ability of using software tool is supported by other two experiments. Further, two types of ability can be trained during the learning process of the Quartus II software: one is grasping the schematic design method which can be supported by the Exp.2, the other one is grasping the Verilog design method which can be supported by the Exp.3.

Thirdly, the ability of complicated sequential logic design, which can be directly supported by the Exp.5, need to be formed on the basis of two design abilities: simple combinational logic design (supported by the Exp.3) and simple sequential logic design (supported by the Exp.4).

In addition, the Exp.3 acts as a bridge connecting the ability of using tools with the design ability. It provides a transition region for students to adapt the change of ability training, and makes the experimental teaching process more fluid.

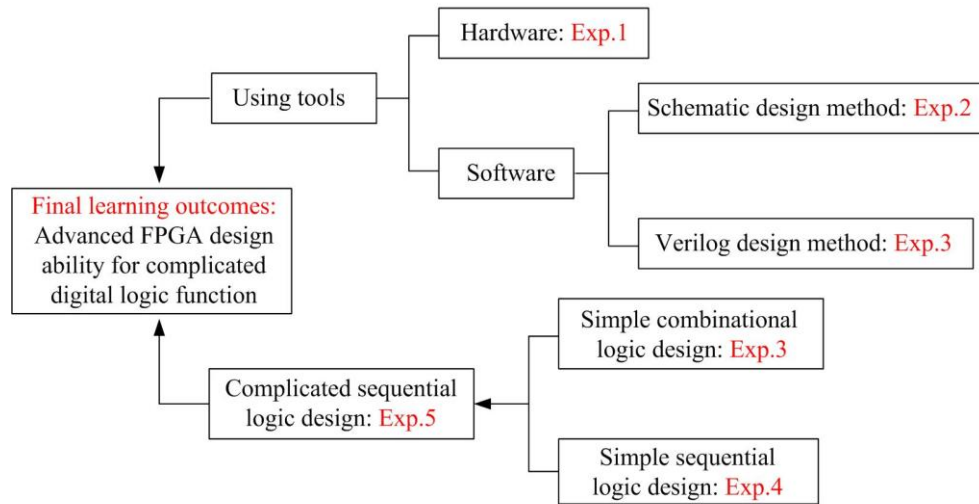


Figure 1 The mapping relation between experiment contents and different abilities

4. Summary

A series of experimental cases in FPGA Technology have been systematically improved combining with the OBE educational idea. The reform of experimental teaching provides more close connection between the experiment content and the ability training. It is helpful to overcome the shortcoming of traditional FPGA experimental teaching and improve students' ability to solve complex engineering problems.

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