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VHDL Digital Electronic Circuit Design Project Based Learning Experience

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Abstract

In this post, we discuss our experiences using VHDL to teach students about system design and digital electronic circuits using FPGAs. For the duration of the course, students will engage in hands-on, project-based learning as they learn to develop digital circuits and systems. Students build increasingly complex electronic circuits as the semester progresses. Students graduate from this class with the ability to work on projects that are both simple and complicated, such as video games and image processing systems.

1. **Introduction**

There has been a remarkable rise in the usage of digital electrical circuit design tools such as programming logic devices (CPLD, FPGA), computer-aided design (CAD), and other tools over the last several years. The ACM (Association for Computing Machinery) and the IEEE (Information and Communication Technology) have recently endorsed the inclusion of these technologies in their ICT forecasts [1, 2]. According to [3-5], some examples of digital electronic coursesFPGA-based. Learning through project-based activities helps students develop their critical thinking and problem solving skills, as well as their ability to gather and analyze the data needed to identify and fix problems in the real world. (PBL) Project-Based Learning strategies have been proven to be effective [6-8]. ECTS, the European Credit Transfer and Accumulation System, is currently being implemented in Spain [9]. ECTS stands for the combination of modern teaching approaches that focus on involving students more actively in the learning process. Lesson instruction is less important than training activities, in which the student plays the primary role. This article defines a practice that was employed in the 2003-04 academic year for training the course: Electronic Circuits Systems Design. A two-year-old practical practice and its results are described in this article.

2. EducationalBackground

The ECSD course is a 60-hour (60 credits) fourth-year requirement. Fig 1 depicts the routes that were previously linked. students in the fourth course appear to have a solid foundation in electrical circuitry and analog electronic circuits. In addition, the student has completed two 4.5-credit digital electronics courses. Logic and logic-block theory were covered in depth in the first (DE1) course, which served as a foundation for all subsequent courses. Using FPGAs, students have mostly learned how to build diagramsinthiscourse[10].

year - semester Analog Electronics Digital Electronics Computer Essentials

1-1

1-2

CAD (6cred) Circuit analysis
&design

ECM(6cred) Electronic Components and Measures DE1 (4.8cr)

Digital Electronics I
2-1

2-2
AE(6cred) Analog Electronics
DE2(4.8cr)
Digital ElectronicsI
I CF1(6cr)
Computer
Fundamentals I
CF2(7cr)
Computer Fundamentals II

3-1 SED (7cr)
Digital
Electronic Systems
4-1
ECSD (6 credits) Electronic Circuits & Systems Design
Fig 1: Previous courses related to ECSD

This course has allowed students to gain experience in digital design throughout the term. VHDL and finite state machines have been taught to the practice of designing abstemiously complex digital circuits. Computer architecture is also taught to students (CF1 & CF2). In addition, students worked with microcontrollers both theoretically and in the practical labs during the course of Digital Electronic Systems.

3 Course Purposes andContents

The primary objective of the course is to expose students to the complexities of real-world digital electronic systems while demonstrating the advantages and disadvantages of various design alternatives. Apprentices will have a thorough understanding of digital electronic design and computer architecture by the end of the course; they will have accumulated information from previous courses.

Comprehend and weigh the advantages and drawbacks of each potential replacement in terms of the following factors:

•AbletouselatestCADtoolsandprogramminglogic devices

Ability to create digital filters and arithmetic components.

Intricate testing methods for their designs are possible.

- Develop better teamwork abilities

The purposes are structured asfollow

Topic	**Contents**
T-1	Overview to electronic systems - Digital electronic systemdesign - System provisions and constraints - Microprocessors, programmable devices,ASICs
T-2	Programing logic devices - Evolution - Architectures
T-3	Computer-aided design tool - Synthesis and simulation (Xilinx ISE, Modalism)

T-4	Design methodology - VHDLdesign - Modular and hierarchicaldesign - Design forsynthesis - Generic and configurabledesign - Design for reuse, Intellectual property(IP) - Teamworkdesign
T-5	Circuit test and verification - Test-benchdesign - Test-based design strategies, design for test(DFT)
T-6	Arithmetic circuits and digital filters design - Adders and subtracters - Multipliers anddividers - Digitalfilers
T-7	Synchronization and interfacing - Asynchronouscommunication - Protocols andautomobiles
T-8	Optimization - Demonstration, area, powerconsumption - Pipelining and parallelprocessing

A digital electronics lab is used for the course. Xilinx ISE [11] is used to implement designs in the V2-P Development System

3. **Methodology**

PBL is used as a teaching method in this course. In place of pursuing a course based on Table 1, we've recommended projects that expose students to these topics. In this way, circuit design students experience new challenges throughout the course, which necessitates them to become immersed in different systems to solve these problems. Students have already proved their mastery of digital design, computer architecture, and analog electronics in earlier courses. That's why students will be expected in this course to apply what they've learned from previous courses to the real-world challenges of digital electronic design. They'll also be expected to demonstrate their ability to do so. Course modules include seminars, supervised laboratories, and a final assignment.

A semester's worth of theoretical lessons is packed into a single session. These lectures provide an overview of the key themes, as well as specifics on each of the assigned research labs and the overall project. During these classes, students learn about the challenges they'll face and the unconventional strategies they might use to overcome them. Additionally, a library of sources is available for further research.

The course's guided laboratories are its most effective teaching tool. Students work on creative projects that get harder and harder as the semester goes on. Prerequisite experience is gained through these projects, allowing the students to handle the final assignment.

Fig. 2 depicts the course's guided research laboratory. There is a handout for everyone, in which they can see the new tasks [13, 14]. Groups of two students complete both the guided research laboratory and the final project. The final project is a large and sophisticated digital design that incorporates all of the principles learnt in the lab. By now, students should feel confident enough to come up with their own ideas for capstone projects. Unusual project methodologies and estimates of project complexity are both examined by the teacher and students alike Image processing and video game development are the most common options for students.

The bare minimum requirements for the computer game were the use of ROM to display images and compile alphanumeric scores from bitmaps. In more advanced projects, peripherals like the mouse and keyboards were used, as well as additional bonus points and lives. As a result of the use of classic computer games like Pac-Man, Super Mario, and Tetris (figure 2). The serial port is widely used to receive images for image processing projects. After that, operatives like Sobel or the Mean are used to refinethedata

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#	Laboratory	Hours	Objectives
1	**Basic board operation**	**2**	- **Know the developmentboard** - **Introduce the developmentenvironment** - **Check the proper function of thesystem** - **Push-buttons and LEDinterfacing**
2	**Simulation**	**2**	- **Simulationreview** - **Herramientas parasimulations** - **Differences between VHDL for synthesis and simulation**
3	**Shift registers**	**optional**	**- Review of former courses (DE2)**
4	**Finite state machines**	**optional**	**- Review of former courses (DE2)**
5a	**UART transmitter**	**12**	- **Design a circuit moderatelycomplex** - **Design complextestbenches** - **Generic design** - **Understand the challenges of asynchronouscommunication** - **Assimilate what have been learned in formercourses**
5b	**UART transmitter-receptor**	**8**	- **Hierarchicaldesign** - **Reuse** - **Generic design** - **Study in depth testbenches andsimulation**
6	**VGA controller**	**8**	- **Timing andsynchronization** - **Be able to design a complexcircuit** - **Understand how common deviceswok** - **Study in depth testbenches andsimulation** - **Get a glimpse of the possibilities of digitaldesign**
7	**Tennis videogame**	**8**	- **Mathoperators** - **Concurrency** **- Deeper understanding of timing & synchronization issues**
8	**PS/2 port**	**optional**	- **Reuse** - **Concurrency** **- Interfacing, input/output ports**
9	**Math operators**	**optional**	- **Parallelcomputing** - **Pipelining** - **Understand the complexities of mathoperators** - **Performance, area and powerconsumption**
10	**Draw images in screen**	**optional**	- **ROM, memoryaddressing** - **Imagestorage** - **Timing andsynchronization** - **Mathoperators** - **Reuse**

11	**Character writing in screen**	**optional**	- **Timing andsynchronization** - **Reuse** - **Hierarchicaldesign**	- **ROM & RAM, memory accesscontrol** - **Systemintegration** - **Complex systemsimulation**
12	**Digital image processing**	**optional**	- **Mathoperators** - **Digitalfilters** - **Timing andsynchronization** - **Reuse**	- **ROM & RAM, memory accesscontrol** - **Hierarchicaldesign** - **Systemintegration** - **Complex systemsimulation**

Table 2: Compulsory and optional laboratories

5 Results

In order to evaluate this course, we looked at the results students attained and the level of satisfaction they showed at the end of the course.

5.1 Academicresults

80 percent of a student's final mark is based on their ability to complete a project to its completion. The theoretical examination provides the missing points. The final grade might be improved by as little as one point if student volunteers worked in the lab. In spite of the fact that students must present their final project in order to receive a mark, the university teacher is always available to answer questions and resolve discrepancies. This allows for a more comprehensive grading system. Students can estimate their marks and decide how much time and effort they want to put on the design. When it comes to their final exam scores, students are more evenly distributed across the board. Second-year theory exam marks may have suffered since some groups hadn't concluded their design alteration exams and hence didn't have sufficient background knowledge of certain topics. Despite this, students tend to spend more time on lab work since they know that the design is the most important part of their grade.

	year 2007-08			**year 2008-09**		
	Exam	**Project**	**Final**	**Exam**	**Project**	**Final**
Fail	**16%**	**11%**	**11%**	**48%**	**10%**	**10%**
C	**16%**	**37%**	**37%**	**24%**	**28%**	**31%**
B	**32%**	**21%**	**21%**	**21%**	**28%**	**31%**
A	**37%**	**32%**	**32%**	**7%**	**34%**	**28%**

Table 3: Distribution of gradesobtained

5.2 Students requested that the second-year exam be moved up by a few days. Although this may have contributed to poor results, students have a period of time to work on the subjects they didn't understand in order to improve their grades. Students who fail the first theory exam should be required to retake it[15]. This is an excellent idea.

5.3 Evaluation of the course by thestudents

The students' evaluation of the course is based on the University's authorized reviews and an unsigned and volunteer survey conducted on the day of the exam.

A total of 85.1 percent of students completed the official survey that was made available. The following are our top picks for each section, ranked from 0 to 5 stars:

- Organizing and preparing the curriculum:3.9

- Methodology of instruction:4.4

- Level of student participation: 4.1

- Is the course content engaging?

4.5As a result, students are surveyed when they are still struggling to have a comprehensive understanding of the material. In the 2008-09 classes, 75 percent of the students filled out the lecturer's volunteer evaluations, compared to 77 percent in the previous year. Responses are shown in Table 4 belowTable 3: Distribution of gradesobtained

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		07-08	08-09
1	Do you like digital electronics?	1.8	1.8
2	Do you find it useful for your professional future?	1.5	1.4
3	Did you like the course?	1.8	2
4	Do you think you have learned?	1.8	1.8
5	Would you like more (2) or less (0) contents?	1.9	1
6	Do you like the course being so practical?	1.8	1.7
7	Do you agree with the evaluation method?	3	3

Table 4: Summary of the course evaluation by the students 0: Little; 1: Normal; 2: A lot.

The rest of the survey is not comprised as the queries were qualitative and necessary a piece of text as an answer.

Figure 2: Two final projects: Arkanoid & image processing

6 Conclusions

We have a gap in our digital electronics design course training expertise based on Project Based Learning. From our perspective, we are really confident in the results. As a result of taking the course, students have a better understanding of their own abilities as designers. It's worth noting that students first find the prospect of working on a project of this scope very unpleasant, but once they've completed it, they realize they understood a lot more than they thought they did. They also learn to collaborate in groups and analyze alternative designs before implementing the final product. The disadvantages of less-than-ideal solutions become apparent when they begin to work on an issue in a less-than-ideal manner. It's not uncommon to see kids from various classes working together to solve problems. There were many students who expressed their appreciation for the course's approach to learning, which was based on a real-world perspective and was fun to watch. Some of the students appear to be doing a Master's Thesis in electronic design after finishing this course, which is part of a five-year degree program. However, some students find this practice difficult to adapt to, and it might be difficult to evaluate theoretical understanding. On the other hand, implementing a project-based learning strategy requires more time and resources when there are more students per session.

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