A VLSI Design Course in a Resource-Constrained Environment

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Abstract

An important area in Electrical Engineering is VLSI design, which concentrates on the development of integrated circuits, or chips. Thus, several Electrical Engineering departments offer VLSI design courses as technical electives for seniors and graduate students. Since the goal is to develop practical design skills, these courses often require students to design, manufacture, and test actual chips. However, this requires expensive resources that exceed the budget of many small departments.

The Electrical Engineering department at the University of Tulsa has nine faculty members, 50 seniors, and 20 graduate students. Therefore, our budget does not allow us to offer courses that require expensive resources. However, our students are still interested in VLSI design. Thus, we have developed a VLSI design course to fit within our budget.

The course starts with basic VLSI design theory. Students apply this background to develop simple circuits using CAD tools. After they become familiar with these tools, the students form project teams to design simple chips. Since it is expensive to actually fabricate the chips, the design operation and testing are simulated using the CAD tools. Thus, the students are able to practice their VLSI design skills without the need for expensive manufacturing resources.

Background

A VLSI (Very Large Scale Integration) circuit contains a large number of components that are integrated on a chip to perform specific system functions. Many contemporary electronic circuits are designed and manufactured using VLSI technology. It is important for Electrical Engineering departments to include topics in VLSI circuit design in their curricula.

Several universities have developed courses to address this area [1-4]. Since the goal is to develop practical design skills, these courses often require students to design, manufacture, and test actual chips. However, this often requires expensive resources that exceed the budget of many small departments.

Proceedings of the 2003 ASEE Midwest Section Meeting
University of Missouri-Rolla

The Electrical Engineering department at the University of Tulsa has nine faculty members, and approximately fifty seniors and twenty graduate students. Therefore, our budget does not allow us to offer courses that require expensive resources. However, we still wanted to offer a VLSI design course to meet the needs of our seniors and graduate students. Therefore, we had to develop a course that would fit within our budget, but still allow students to develop the necessary design skills.

This course was initially developed to be one of ten technical electives at the senior/graduate level that are offered on a rotating basis. One of the authors (Kane) participated in an NSF sponsored program on VLSI instruction in 1989 – the material from this program was used to develop our first VLSI design course. The department also participated in the Mentor Graphics software sharing program, which provided access to industrial-level VLSI design tools. Unfortunately, departmental budget limitations forced us to discontinue this program. Thus, we revised the course to meet these limitations.

Implementation

VLSI Design is a one semester (15 week) introductory course that is offered to as a technical elective for seniors and graduate students in Electrical Engineering. The prerequisites for this course are basic digital systems principles and electronic devices courses that are required for all Electrical Engineering undergraduate students. We use the text by Rabaey [5] and cover the core material as recommended by the author. First, we review the operation of electronic devices (diodes and field-effect transistors) that are used in integrated circuits. Next, we discuss how to construct digital logic components from these devices. Finally, we discuss design and test methods for implementing these components on a chip.

At many universities, students design, fabricate, and test actual chips. However, this requires costly resources. While we want our students to gain practical design experience, we need to use resources that fit our budget. In order to meet this goal, we have the students simulate chip design by using CAD (Computer-Aided Design) tools. This allows our students to practice their VLSI design skills without the need for expensive manufacturing resources.

When we selected the appropriate CAD tools for our VLSI design course, there were certain criteria that were important. First, the tool must meet our basic VLSI design needs: it should allow a user to simulate the design and operation of a chip. Next, we need a tool that meets our budget constraints. The tool should be relatively inexpensive, and should also run on our current computing system. Finally, the tool should be relatively easy to learn, for both the students and instructor.

Given these criteria, we selected MicroMagic, a commercial CAD tool for integrated circuit design. Since we were an academic institution, we were able to get free licenses if we agreed not to use the tool for commercial applications. This tool runs on the Unix workstations in our labs,

which had been underused since most of our other software packages run on Windows workstations. We use two programs: SUE for circuit schematic design and MAX for circuit component layout. Both of these programs have good tutorials and are easy to use. Tutorial exercises are incorporated into homework assignments – students do the manual work, and then they follow up with the application of the CAD tools. By the time projects are assigned, the students are familiar with the basic functions of MAX and SUE. Students work on tutorials individually, and then work in groups on the main project.

While MicroMagic has been proven to be an effective CAD package for our course, this tool is no longer sold or supported. Although we able to get an extended license from the manufacturer, we will eventually need to find a replacement CAD tool.

In addition to design with CAD tools, the graduate students research current methods in VLSI design and write a research paper on a specific topic. They start with reading assignments that supplement the course text –these concentrate on more recent and specific areas. A survey paper is given for the first reading assignment in order to give general background information. The students answer specific questions about key points of this paper. Next, each student selects an article that is cited in the survey paper, then reads and writes a short report on this article. Finally, students select a recent paper in a related area – this paper will become a seed paper for their research paper.

Observations and Outcomes

The course has been taught using the current material and design tools for the past three spring semesters. Most students are able to learn the basics of MAX and SUE, and are able to complete basic circuit designs for their projects. Some of our former undergraduates are now working on VLSI design projects in industry. The graduate students develop research skills that can be applied to their thesis work. At least one student has expanded his research paper into a master's thesis, and is currently pursuing doctoral studies in VLSI design at another university.

References

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