Implementing PLD Technology in An Introductory Digital Logic Course

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Introduction

This paper describes a project accomplished in a partnership between the Department of Engineering Technology (ETEC) at the University of North Texas (UNT) in Denton, Texas and Altera Corporation in San Jose, California. The purpose of the project was to upgrade the digital logic course lectures and laboratories to incorporate the latest hardware and software technologies. The major thrust was in the laboratories resulting in new equipment, remodeled facilities, greater use of computer aided engineering software, and enhanced learning activities.

Previous laboratory experiences

For the most part, the digital logic course is taught as in most engineering technology curriculums.
The lecture covers topics beginning with binary concepts and progressing through combinational and sequential devices. Laboratory experiences are designed to complement the theory studied in the lecture classes. Both analysis and design concepts are introduced.

The previous computer design and analysis software were several generations behind current computer aided engineering software. The software relied heavily on text commands. The design process required generating tiles in various formats to be used by other programs to generate logic diagrams, perform simulations, and generate waveforms and state tables. The experience was less than desirable considering that today's students are accustomed to windows-based integrated applications sotlware.

Once a digital logic circuit was designed, it was tested using traditional breadboard systems that included switches, power supplies, LED indicators, etc. As the students gained knowledge and experience, the task of testing increasingly complex digital logic circuits became a limiting factor in their laboratory experiences. Mainly the combination of outdated software and complex wiring on the breadboards were the problem, not the underlying digital logic theory. In addition, student designs were limited to the inventory of components and devices available in the parts storeroom.

Alternatives to traditional integrated circuits

An alternative to using standard integrated circuit devices is to implement the logic design in programmable logic devices (PLD). A PLD is a device that contains large numbers of gates, flip flops, and registers that are interconnected on the chip. Specific digital logic designs are implemented through the process of programming the device. In some cases, the devices are programmable only once because fusible links are actually blown to create the design. Other PLD devices, similar to EEPROM memory devices, allow the reprogramming of devices so that new designs may be implemented.

Companies that manufacture PLDs must also provide the software tools and programmers that allow designers to implement their designs. It was determined that by introducing the use of PLD devices and software tools in the laboratory, students educational experiences would be enhanced by:

- creating more interest in the design process through the use of graphical based programming and simulation tools
- allowing more complex designs to be achieved in the courses since greater efficiency would be experienced through use of modem software tools
- eliminating student frustration and loss of interest due to tedious, nonproductive time required to troubleshoot breadboarding errors rather than design problems
- providing students with skills and knowledge to use the technology in subsequent courses that require digital logic circuits such as microprocessor interfacing, control systems, and senior design.

A careful study was conducted of various companies that provide logic design and simulation software. The possibilities ranged from stand alone software such as ORCAD Schematic Capture and PLD Design Software to proprietary packages provided by companies such as Texas Instruments, Xilinx, Motorola, and Alters.

Altera Corporation is a world leader in high performance programmable logic devices and associated design and analysis software. They shipped the worlds first programmable logic chip in 1984 and remain at the forefront of the technology providing high-speed, high density and low power devices. In addition, the Altera University Program provides engineering students with knowledge and experience of designing, simulating, and implementing digital logic designs using PLD technology. The program is open to any accredited university, college, community college, or trade school. Alters maintains a WEB page where news, technical data, and other items relating to PLDs maybe obtained.

The Engineering Technology Department at the University of North Texas and Altera Corporation joined in a partnership to upgrade the digital logic laboratory facilities, equipment, software, and instruction. UNT provided a laboratory facility with new computers at each student station, network server and cabling, and connection to the campus Ethernet fiber optic backbone. Altera Corporation provided the Multiple Array Matrix Programmable Logic User System (MAX+PLUS II) design and simulation software, PLD programming equipment, manuals, technical support during startup and implementation, and PLD devices for use by students.

Digital logic class overview

The ELET 2720, Digital Logic class is offered each semester including the summer session. The course is taken by sophomores that have a computer programming class as prerequisite. Both computer science and electronics engineering technology students enroll in the course. During long semesters, 45-50 students enroll in the class. Laboratory sections are offered so that no more that two students are at each of 10 laboratory stations. In addition to normal laboratory periods, the facility is made available to students during open laboratory times.

In the digital course, the students use the Altera MAX+PLUS II software to design circuits in the schematic entry mode. Waveform analysis and simulation are performed to check designs. Once satisfied with the circuit design, students use Altera device programmers to download the configuration into an EPM 7032 PLD. Finally, the programmed PLD is breadboarded with other components such as switches, LED's, LCD arrays, A/D and D/A converters, and various transducers to verify the logic system performs according to specifications. Lastly, outputs from the design software such as schematics, waveforms, state tables, etc. are incorporated in laboratory reports to document the design and results of testing.

The lecture course includes videotapes, lectures, and problem solution to cover the logic theory. The class is limited to those with a previous computer programming course and majoring either in computer science or engineering technology. The textbook is Digital Systems Principles and Applications, Fifth Edition, by Ronald J. Tocci, Prentice Hall

Publishers. The lecture topics are typical as found in most entry level digital logic courses. The major topic areas are:

- Number Systems and Codes
- Boolean Algebra
- Logic Gates
- Combinatorial Logic Circuits
- Flip-flops and related devices
- Digital Arithmetic Operations and Circuits
- Counters and Registers
- Integrated Logic Families and Characteristics
- MSI Logic Devices
- A/D and D/A Converters
- Memory Devices.

Laboratory equipment and software

There are twelve laboratory stations in the room. One of the stations is a print station with a print server and laser printer. The remaining stations consist of 90 Mhz Pentium PCs with and 32 megabytes of memory. All computers are connected by Ethernet cabling to a dual processor Pentium server. Access to the application software is available through the campus network from other computing centers, dormitories, and faculty offices. In the near future, controlled access through dial in telephone lines will accommodate distance education students. Other equipment in the laboratory is consistent with traditional digital laboratories including logic analyzers, oscilloscopes, digital voltmeters, and other instruments.

The MAX+PLUS 11 development software is a fully integrated package for designing circuits to be implemented using PLDs. The MAX+PLUS II development environment provides for a full range of logic design capabilities for design entry, verification, and device programming. Various design entry methods are allowed using integrated tools such as a text editor, graphic editor, waveform editor, symbol editor, and floorplan editor. For project verification MAX+PLUS 11 provides software tools for simulation, timing analysis, and waveform verification. The devices are programmed using integrated device programming software. The MAX+PLUS II also allows the exchange of data with other application software through software interface. In addition, it is capable of both reading and writing standard EDIF netlist files, VHDL Design Files, and ORCAD schematic files. A fully illustrated help system is available through a menu option.

The Altera University Program allows students to load a subset of the MAX+PLUS II system (PLS-ES) on their home computers. This is extremely helpful as it allows for homework assignments and projects to be developed without requiring the physical presence of the students in the laboratories. A required authorization code is obtained by students contacting Alters directly. The PLS-ES feature set allows students to enter designs by activating the schematic capture program, logic synthesis, error checking, and timing analysis of the MAX+PLUS II system.

Laboratory assignments

Because of the unique nature of the software and hardware used in the laboratory, new laboratory handouts were developed for students. These are stored on the network server and downloaded by students as needed. The laboratory assignments consist of:

- Introduction to Schematic Capture and the Altera MAX+PLUS II Design Software
- Constructing combinatorial circuits
- logic simulation of combinatorial circuits
- minimizing circuit designs with Boolean algebra
- circuit design with Karnaugh Maps I
- circuit design with Karnaugh Maps II
- combinatorial circuit design using programmable logic devices

- logic simulation of flip-flops and latches
- logic simulation of sequential circuits
- synchronous counter design
- comparator circuits
- using A/D and D/A converters in digital circuit designs,

Conclusion

The project to upgrade the digital logic laboratory is a success. Comments provided by students on course evaluations document their enthusiasm and satisfaction with the new approach. Without its corporate partner, Alters Corporation, the project would have been difficult to achieve because of the costs associated with acquiring design and simulation software. All the goals have all been met even though additional fine tuning of the laboratory exercises is in process. Students work with traditional integrated circuits including 54/7400 TTL, A/D, D/A, and memory devices. They gain additional knowledge as a result of using PLDs to implement their digital logic designs. In addition, the students become more proficient in the use of state of the art computer assisted design and simulation software. Feedback from students on course evaluations indicates a high degree of satisfaction with the new laboratory format and use of modern devices and software. It is anticipated that courses beyond the digital logic course will see increased student interest and better logic circuit designs as a result of the knowledge gained in the use of PLDs and associated software.

Details about the Altera University Program are available on the World Wide Web page that is located at http: //www.altera.com. Additional information or copies of laboratory assignments based on the MAX+Plus software are available from the authors by request to email address bgrubbs@cas.unt. edu..