ASEE 2012: DEVELOPING TODAY'S NEW TECHNOLOGIST USING RECONFIGURABLE SOLUTIONS

Undergraduate Student Paper

Undergraduate Engineering Education

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Abstract

The gap between what the Community College can offer and what the University can offer (in terms of digital logic education) continues to widen. This is in large part due to the fact that Community Colleges do not have access to the relatively inexpensive labor that Universities are provided via the Research Assistant programs. This paper will present details related to a National Science Foundation (NSF) funded program designed to overcome many of the barriers to modernization.

There is a belief that the pathway ahead for the American technical community is through the integration of more programs that can be used for rapid development and prototyping of systems into the classroom. Field Programmable Gate Arrays (FPGAs) provide this capability. Every system developed today from the simplest child's toy to the most complicated weapons system contains a "brain". That device is either a microcontroller or an FPGA. For today's modern workforce to be truly competitive, they must be exposed to these systems early in academic programs.

The NSF has funded the University of New Mexico (UNM) and four Community Colleges through their Advanced Technological Education (ATE) program to provide instructor training across the country. To date, instructors from 40 Community Colleges and 20 Universities have been formally trained. The currently funded NSF ATE grant is focused entirely on curriculum development and academic training for FPGAs. The grant funds beginners and advanced FPGA workshops across the country.

The Problem

Technicians and engineers need to be taught basic digital logic. The theory of teaching this subject hasn't changed in 20 years. Unfortunately, the same cannot be said for the associated technology and tools. Often, schools continue to teach basic digital logic using 7400 chip. These devices are obsolete, difficult to find, often cannot be combined into larger projects and, if you can overcome all these hurdles, you will have trained students on technology no one uses. There are many examples of where universities have begun teaching with FPGAs and other digital devices for basic logic courses at universities [1-5].

All modern electronic systems are built upon some type of digital control system. These digital control systems most often fall into one of two broad categories as "brains". The categories are: FPGAs and microcontrollers. The main decision point between the two devices often has to do with the number of inputs and outputs. If that number is relatively low, the use of a microcontroller is usually more desirable. If there is a need for several hundred inputs and outputs, the selection of an FPGA makes more sense. Regardless, modern digital designers must have a working knowledge of both of these families of devices to compete in today's marketplace.

Background

To better understand how FPGAs and Microcontrollers effect modern systems development, it is important to first understand the two devices in a little greater detail and their role in today's workforce.
Field Programmable Gate Arrays: In the past 20 years, electronic devices have gone from hundreds of logical gates to hundreds of thousands of logic gates. Similarly, solutions that use to require boards full of electronics can now be accomplished with single chip solutions. The two largest FPGA manufacturers are the Xilinx [6] and the Altera Corporations [7].

As shown in Fig 1, every FPGA is comprised of three basic elements. These elements are: Look-up Tables (LUT), some carry logic and a register. Combinations of these items make up a "slice". Combinations of slices make up a Complex Logic Block (CLB). All FPGAs have CLBs of different sizes

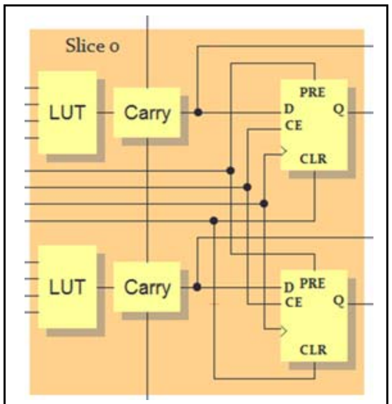

FIG 1. FPGA Slice Configuration

and with different capabilities.

The educational partners described in this document have been funded to create an extensive series of curriculum for FPGAs using a Very High Speed Integrated Circuit (VHSIC) Hardware Descriptive Language (VHDL).

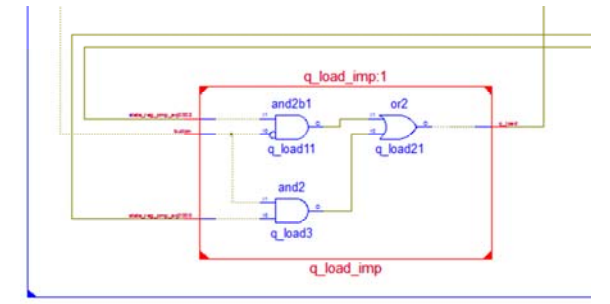

FIG 2. RTL Viewer

VHDL is the standard by which the majority of FPGAs are configured. The VHDL is synthesized into slices which are then mapped into the logic of the FPGA. The Xilinx tool provides the capability to be able to see how the design is developed in a traditional Register Transfer Language (RTL) view. As shown in Fig 2, many designs created in VHDL can ultimately be represented by combinations of AND and OR gates. Preliminary results from a recent industry assessment survey showed that almost ¾ of the respondents view knowledge of VHDL as a critical skill for making a technician more employable and marketable (as shown in Fig 3).

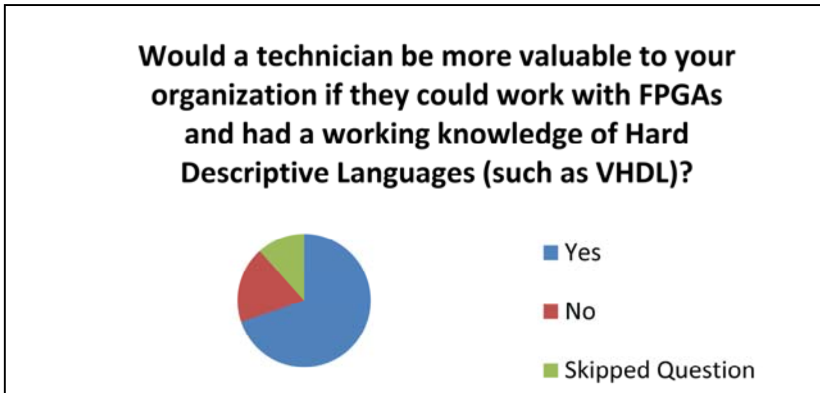

FIG 3. VHDL is required

A critical difference between FPGAs and microprocessors is related to VHDL. Where a microprocessor can execute only a limited set of instructions based on a rigid architecture, an FPGA can be dynamically configured a limitless number of different times (and ways) using VHDL. Hardware descriptive languages like VHDL are not a programming language. They are ways to “describe” combinations of hardware. VHDL descriptions can be combinatorial (no clock) or synchronous (clocked). Although FPGAs and VHDL fit into a digital logic or computer architecture course, their robust capabilities allow them to be applicable to a wide range of different courses as shown in Fig 4.

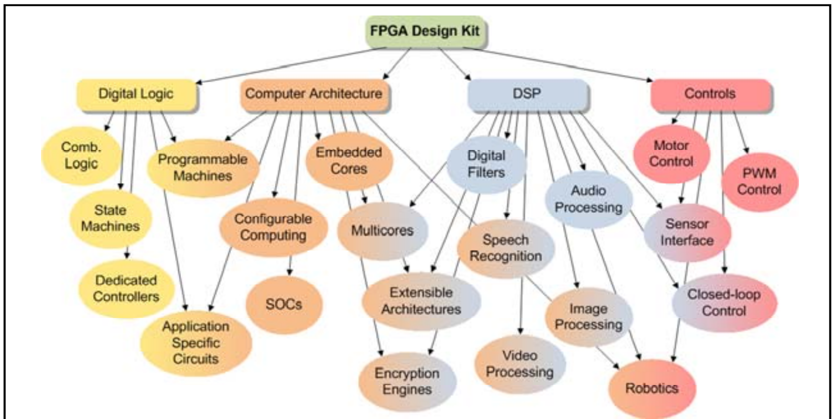

FIG 4. FPGAs Fit into Various Courses

Microcontrollers: Another very popular form of configurable electronics is the microcontroller. Microcontrollers are the 'little brother' to FPGAs. These low-power systems provide a more cost-effective, simpler alternative to the thousand-pin high performance processing capability of FPGAs to control smaller systems. They are often the device of choice when teaching controls courses as they are easy to understand and less complicated to work with than traditional microprocessors.

The Microcontroller is sometimes called a system on a chip. Microcontrollers contain a microprocessor, memory, and peripherals that allow it to communicate to the outside world. These embedded systems have grown to dominate the life of the average person. From automobiles, home appliances, cell phones, portable music players, personal digital assistants, thermostats, calculators, automatic teller machines, control systems, and even on some credit cards, our lives are bombarded with embedded systems that run on a microcontroller. The knowledge of both FPGAs and microcontrollers are essential for today's instructors to be able to deliver relevant tools and training to their students.

The ATE Project

In August 2010, the National Science Foundation (NSF) awarded the University of New Mexico and four partner community colleges funds to develop a series of laboratory tutorials and curriculum. This work was promoted through the NSF Advanced Technological Education Program [8]. Then the team was tasked to teach 30 instructors each year (for three years) on how to implement basic digital logic with FPGAs and VHDL and how to take this knowledge into their classrooms. In the first year, beginner and advanced courses were taught in Arizona, New Mexico and Alabama.

Each of the three sets of workshops are two days in duration. The beginning workshop covers items such as basic FPGA architecture, VHDL design and combinatorial circuits.

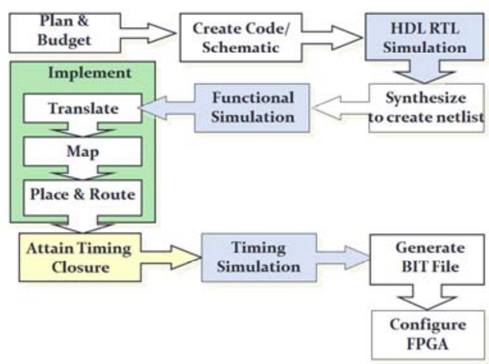

FIG 5. Xilinx Design Flow

It is assumed that an individual enters the basic workshop with only rudimentary understanding of the theory of digital logic. The individual leaves the basic course with enough information to be able to complete fairly complex combinatorial circuits in hardware using either a schematic capture or VHDL design paradigm, and be able to demonstrate the design in hardware. All instruction revolves around the Xilinx design flow (shown in Fig 5). From the simplest to the most complex FPGA project, the design flow is the rule. Simulation instruction is provided to allow instructors to be able to understand how to test their designs prior to configuring the hardware. The advanced course usually occurs three months later. It begins with a very quick review of what was covered in the introductory course. The two-day advanced course covers the following topics in VHDL: Counters, Sequence Detectors, Testbenches, Finite State Machines, and other related topics.

During both courses, time is devoted to discuss possible strategies and hurdles that the instructors might encounter in implementing this new technology in their classroom and statistical information is collected. The desire is that when instructors finish the series of courses, they have all the necessary skills to be able to begin instruction at their schools.

Current Status

In 2012, courses are currently scheduled for Texas, Oregon, and South Carolina. To date, more than 60 instructors have been formally trained. The team is so successful and the demand is so strong that the team is now planning on teaching approximately 140 instructors this year. In August, 2011, the ATE team sent out an email to the ETD listserve email listing with information about possible workshop opportunities. They received approximately 200 emails in 48 hours.

Workshops from a student perspective

One of the individuals taking the two day beginners course was Chelsea Kief. Kief is a Junior in computer science at Highlands University. Her views are critical since she (and other students) are what the ATE grant intends to produce in terms of marketable students. Listed in this section are her thoughts.

Taking a FPGA and VHDL course was not only exciting, but a very influential experience. It helped open different aspects of technology that are more of personal interest and beneficial. There was very little information and insight provided about FPGA and VHDL prior to the beginning of the workshop. It helped provide a foundation for a future education and career path pertaining to this technology. The course was well instructed and provided the fundamentals of logic design. Utilizing the FPGA board created sustainability of knowledge as well as a quality increase of my coding skills. The fascination was depicted through instantaneous results from the hardware after personal implementation of coding. This experience advanced my aspirations for the future. In result, there is personal motivation and perseverance to pursue a career in electrical engineering.

This type of feedback from a student is critical for the ATE team. At a time when more and more students are leaving the STEM disciplines, something like this that can motivate them to stay in STEM fields and work on individual projects of interest to them provides a capability that all schools today are looking for.

Future Work

There are several pending proposals that could expand the efforts of this group into different directions. One of these proposals is in the area of microcontrollers. The NSF ATE team has created the educational system for FPGAs and is actively involved in the outreach section of their ATE project. The team wants to provide the same capability for microcontrollers. The majority of instructors and professors are just looking for assistance in learning new technology so that they can make their students one step ahead of the competition. It is clear that the old way of teaching digital electronics, with 7400 series logic gate chips, needs to adapt to the influx of new technology. This cost effective path of reconfigurable electronic development is not going away. Every company that makes any type of control system uses FPGAs, microcontrollers, or both. They are proving to be the most efficient and adaptable components within every embedded system.

For these reasons, industry will continue to employ these tools for years to come. From an industry perspective, it is critical to be able to get to market fastest and stay in the market longer to be truly successful. Workers must be prepared to work with these devices throughout their career. It is imperative that they receive the proper training on these devices to draw employment opportunities back to this country. By providing a state-of-the-art learning environment, technicians and technologists can become more competitive within the workplace.

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