CIEC 2013: DEVELOPING TODAY'S NEW TECHNOLOGIST USING RECONFIGURABLE SOLUTIONS

Craig J. Kief and Brian Zufelt
Configurable Space Microsystems Innovations & Applications Center
University of New Mexico
Craig.Kief@cosmiac.org and Brian.Zufelt@cosmiac.org

Bassam Matar
Electrical Engineering
Chandler-Gilbert Community College
b.matar@cgcmail.maricopa.edu

Karl Henry
Engineering Technology Division
J.F. Drake State Technical College
Karl.Henry@drakestate.edu

Abstract

The gap between what Community Colleges 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) and Microcontrollers provide this capability. Virtually every system developed today from the simplest child's toy to the most complicated weapons system contains a "brain". That device is either an FPGA or a microcontroller. For today's modern workforce to be truly competitive, they must be exposed to these systems early in academic programs. Engineers and technicians don't have to be experts in this technology but they certainly can't be ignorant of them.

The NSF has funded the University of New Mexico (UNM) and their community college partners through the Advanced Technological Education (ATE) program to provide instructor training across the country. To date, more than 100 instructors from community colleges and universities have been formally trained on FPGA technology. This work is currently funded under two NSF ATE grants and is focused entirely on curriculum development and academic training for FPGAs and microcontrollers. The grant funds beginners and advanced FPGA and microcontroller workshops across the country that are designed to increase the skills that instructors need to teach this new technology.

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 older 7400 chips. 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. The reason industry has abandoned this technology is because the work performed by the 7400 chips is automated in current design tools. 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 and most often fall into one of two broad categories: 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.

What is a "technician?"

To understand why this work is important, it is good to have a better grasp of the target audience. It is the belief of the team that an Engineering Technology Technician should be provided with the fundamentals of physics, engineering, computer hardware, programming, engineering design fundamentals, and computer software program usage. A solid foundation in mathematics, science, communication skills, humanities, and social sciences provides a well-rounded curriculum. The curriculum should not be concentrated on wiring circuits or assemble of a chip based circuit from scratch; students should learn how to use software to run modern equipment. Larger and more complex projects can be undertaken by using software to interface with hardware. High technology companies are looking for people with solid math, science and problem solving backgrounds.

Today, the greater part of a technician's work now deals with a higher level of abstraction. Specifically, he or she works more with larger printed circuit boards containing many integrated circuits, plug-in modules, subassemblies and entire systems (as well as their power and cabling). The technician's work is at a higher level. The focus should be on signal flow through the system and testing the system to see that it meets specific standards. Rarely does the technician replace individual components as was once the case.

Background on the Hardware (FPGA and Microcontroller)

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.

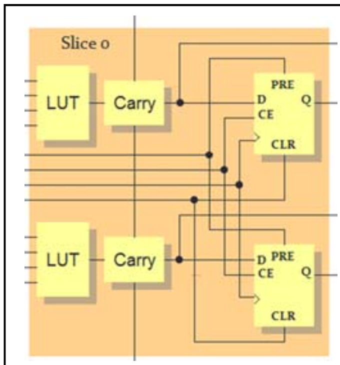

FIG 1. FPGA Slice Configuration

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 once required 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), carry logic and a simple D flip-flop 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 and with different capabilities. However, from the most expensive to the least expensive FPGA, the core components are always the same.

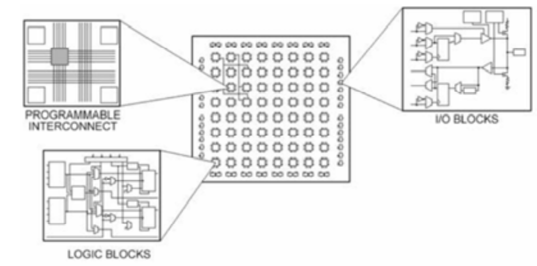

FIG 2. FPGA Infrastructure

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). VHDL is the standard by which the majority of FPGA designs are completed. The VHDL is synthesized into slices which are then mapped into the logic blocks 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. VHDL is a cross platform Hardware Descriptive Language. This means that a VHDL project can target any FPGA.

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 and are used to control smaller systems. They are often the device of choice when teaching controls courses as they are easier to understand and less complicated to work with than larger FPGAs. However, given the cost-effective market of microcontrollers and the rapid growth in manufacturing and performance, microcontrollers are expanding their utility to more projects.

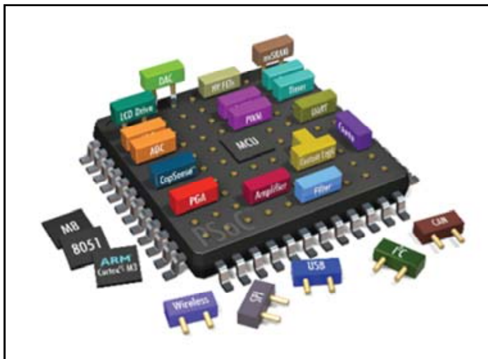

FIG 3. PSoC Overview

The microcontroller can be thought of as an “All-In-One” computer on a chip. For a complete computer system, you need a Central Processing Unit (CPU) to perform all the computational tasks; a storage element to store the processes of a running program; and some control logic to move data. Finally, some memory space to run a program and store applications. When all these elements are found within a single chip, that chip is known as a microcontroller.

The device the team has chosen to use is the PSoC family of microcontrollers by the Cypress Corporation. Shown in FIG 3 is a block diagram view of the PSoC-5 family of microcontroller based on the ARM processor. The ARM processor has become the dominating core found in most mobile devices (smart phones, MP3 players, tablet PCs, etc.). The microcontroller is sometimes called a System on a Chip. This distinction is usually referring to a high performing chip (SoC) and a low-power option (Microcontroller).

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, engineers and technicians to be able to deliver relevant tools and training to their students.

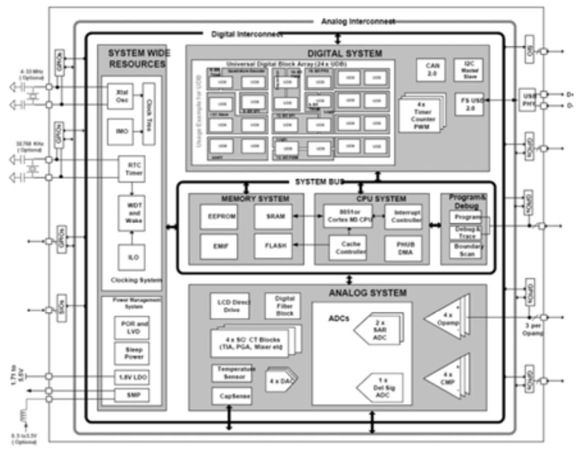

FIG 4. PSoC-5 Functional Block Diagram

The ATE Projects

In August 2010, the National Science Foundation awarded the University of New Mexico and four partner community colleges with funds to develop a series of laboratory tutorials and curriculum for FPGAs. This work was promoted through the NSF Advanced Technological Education Program [8]. So far, beginner and advanced workshops have been taught in AZ, NM, AL, SC, TX and OR.

In August 2012, the NSF awarded J.F. Drake State, UNM and two other schools to be able to develop a similar set of workshops and curriculum for microcontrollers.

It is assumed that an individual enters the basic FPGA 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 is able to demonstrate the design in hardware. All FPGA instruction revolves around the Xilinx design flow. 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 FPGA workshops, time is devoted to discuss possible strategies and hurdles that the instructors might encounter in implementing this new technology in their classroom. The desire is that when instructors finish the series of courses, they have all the necessary skills and materials to be able to begin instruction at their schools.

Current Status

Workshops are currently scheduled across the country. The grant funding to develop microcontroller material is just beginning to arrive. Although the version of the microcontroller has been chosen, no training courses have yet been completed.

Future Work

The team will be submitting an ATE proposal in October, 2012. The main purpose of this proposal will be to provide funds towards keeping the team on the road and teaching. The team has also had meetings between the Cypress Corporation and the Digilent Corporation. Cypress makes the microcontroller the team wants to use and Digilent makes the extensive line educational prototyping platforms. Agreements are now in place that will allow the two organizations to create a platform that the ATE team can use for instructional purposes. The Xilinx Corporation continues to be a strong sponsor of these activities and has donated over $500,000 in software and hardware to educational institutions.

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 new technologies 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 engineers can become more competitive within the workplace.

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