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Hands-on Experience with Altera FPGA Development Boards

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Foreword

The traditional teacher-centered classroom teaching is transforming into the newer student-centered approach to learning. During this transition, the teachers and students need to go through familiarization and training in the new pedagogy. This book entitled “Hands-on Experience with Altera FPGA Development Boards” is an effort by the authors to meet this challenge. The technology space is ever expanding, and it is not possible to teach all of it in the classroom teaching curriculum. It is true that students now have access to vast resources at their fingertips. However, a book of this kind, developed based on the experience of the authors in teaching this to their students, is more suited since it has been improved based on the feedback from the students who have used it in its early form. The authors and their peer group in their department have put in extra efforts to make it student-friendly. This is a third book in the series of books brought out by the group, specifically on the “hands-on-approach” to skill development.

Embedded systems are all-pervading and offer limitless possibilities in the use of FPGAs in systems of diverse nature. This book offers an in-depth, yet practical, explanation of the various elements that make up the subject matter. Understanding the contents of this book does not require high level of prior preparation. The case studies on signal processing and control application are very important for a beginner to put a practical system to work. The students and researchers who wish to explore this area will find it highly useful, shortening their learning time and get them onboard quickly. Authors have extensive experience in this field. They are in academia and understand the needs of students. Also, they have strong connection with industries and thereby have a good grasp of the present status. They have worked themselves on these systems, and hence, the book has a greater authenticity.

I recommend this book for intermediate programmers, electronics, electrical, instrumentation engineers, or any individual who is strongly inclined to take up his or her career in embedded C programming. I am sure the reader will experience learning embedded programming by example and learning by doing. Last but not the least, this book will certainly be a value addition to the field of reconfigurable embedded programming platform.

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Director, BITS Pilani, Goa

Preface

Microprocessor and microcontrollers have revitalized the instrumentation world and now become ubiquitous. However, due to their niche role, when a particular microcontroller is discontinued, the entire product based on it has to be revamped, and the evolution of the technology means that the newer upgraded versions cannot be used in its place due to binary and socket incompatibility. Another issue which arises is of redundant hardware in microcontrollers posing a basic bottleneck in system optimization—many resources remain unutilized for routine applications.

In order to achieve portability, power efficiency, higher throughput, and less latency, the only alternative is to use the soft processor cores with FPGAs for small- and medium-scale production as they become more economic as compared to ASICs. Many vendors have come out with readymade cores such as NIOSII from Altera, Picoblaze and Microblaze from Xilinx. Building the system on FPGAs with these cores will not only facilitate earlier and easier market opportunities but will also give the advantage of using readymade full proof design alternatives, reducing the inconvenience of committing mistakes and debugging. The present book will explore the "know-how" for synthesizing chips for every embedded needs.

Methodologies in digital design have undergone tremendous changes over the past three decades. The use of FPGA and HDL for implementing digital logic has become widespread in the recent past, and use of FPGA in embedded systems is increasing almost day by day. A sign of the increasing importance of this area is that most of the technical institutes and engineering colleges have incorporated FPGA as the core subjects.

The domain of embedded systems is quite large and is centered around general-purpose processors and microcontrollers. The Altera FPGA forum receives numerous posts by newcomers to the technology asking questions on configuring FPGA, interfacing SRAM, building NIOS II system—this book is for those users as it essentially addresses most of these questions. The motivation behind writing this book was to ease out the difficulties faced by the students and researchers, so that they are not dependent on their supervisors to understand the field of reconfigurable embedded platform. To this end, it has many worked-out case studies in different areas of electronics like basic digital designs, sensors and measurement, biomedical instrumentation. It is intended for graduate, postgraduate, and research students from the electrical, electronics, computer and instrumentation engineering backgrounds as a ready reference during their work.

We promise potential readers that this book will reduce the steep learning curve and will help them quickly develop their embedded systems application in the shortest possible time frame. We recommend that the readers begin by reading through the summary paragraphs of each chapter, which will introduce each section and provide an overall picture of how the book is organized and how it will help them in creating their own design.

We would like to thank our student community and friends—their work in various industries helped identify the problems used in the case studies.

Though this book is intended for beginners in the area wherein the students aspire to learn skills building FPGA platform, a prerequisite knowledge in C/C++ and HDL will greatly help in understanding the complexities more easily. Since these two languages are now part of regular curriculum, we feel the students can directly start working on case studies.

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Contents

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Dr. Jivan S. Parab is Assistant Professor in the Department of Electronics at Goa University, India. He completed his Ph.D. from the same university with the thesis titled “Development of Novel Embedded DSP Architecture for Non-Invasive Glucose Analysis.” He received his M.Sc. (2005) and B.Sc. (2003) in Electronics from Goa University. He has co-authored two books, published by Springer. The details of the books are “Practical aspects of embedded system design using microcontrollers” and “Exploring C for Microcontrollers: A hands on Approach.” He has published several papers in national and international level journals and conferences.

Dr. Rajendra S. Gad is Associate Professor in the Department of Electronics at Goa University. He received B.Sc. (Physics) and M.Sc. (Electronics) degrees from Goa University in 1995 and 1997, respectively. He completed his Ph.D. in Electronics in 2009 from the same institute. He has several papers published in journal and conference proceedings to his credit. His areas of interest are biomedical sensors, DSP digital repositories and networks. He has been into teaching and taught courses such as VLSI system design, HDL system design, digital signal processing, computer programming, operating system, mechatronics, and electronics practical.

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Chapter 1
Genesis of PLD's, Market Players, and Tools

Contents

Abstract "Genesis of PLD's, market players, and tools" discuss the microprocessor, microcontroller, and PLD devices and also talk about how to select these devices for desired application. This chapter gives the family tree of PLD devices and helps designer to select best PLD devices based on application. The chapter also gives the overview of major PLD market players and programming aspect of VHDl, Verilog, and ABEL. There are several separate books available in the market which discusses in detail about VHDL, Verilog, and ABEL programming. Here, we simply focused more on the basic part of hardware descriptive programming language.

Keywords PLD · VHDL · Verilog · ABEL

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1.1 Brief Insight of Microprocessor, Microcontroller and PLD's

Microprocessor

Microprocessor in any embedded system design is like a human brain, which provides computational control and decision-making capabilities. Microprocessors find use in advanced electronic design systems such as printers, automobiles, defense. In general, microprocessors have ALU, control logic to generate various control signals, and registers to store data required for processing unit.

Classification of Microprocessors

Microprocessor classification is based on function handling and features supported. The several companies manufacture many variants of microprocessors currently available in market but most frequently used microprocessors are as follows:

Intel microprocessors

4-bit processors: 4004, 4040
8-bit processors: 8008, 8080, 8085
16-bit processor: 8086, 8088, 80186, 80188, 80286
32-bit Processor: 80386, 80486,
64-bit processor: Itanium, Dual core, i3, i5, etc.

Zilog microprocessor:

8 bit processor: Z80, Z180

Motorola Microprocessor:

8 bit processor: 6800

PLD's

A programmable logic device (PLD) is the device in which the designed logic is implemented and easily reconfigured by the programmer on the fly. These devices are called as field programmable logic devices since the designer has flexibility of device programming in same field. The PLD gives designers the flexibility to implement different complex designs for various applications. Programmable read-only memory (PROM) is the most commonly used PLDs. There are two categories of devices: (a) devices are programmed by the vendor using a mask, and interconnects are one-time programmable, (b) devices that are programmed by the user are called field programmable. PLDs are very much inexpensive and flexible which are the biggest advantages.

1.1.1 Selection of Technology Based on Application

In embedded system design, the processor plays an important role on the designed system's success or failure.

Selection of the proper device for right application is therefore extremely important. Embedded application devices are broadly divided into microcontrollers and microprocessors. MPUs come in an extensive range of different types, models, and sizes.

Choosing between a microprocessor, microcontroller, or PLD's is a complex and rather daunting task. Several device selection criteria are discussed below. Selecting the proper device on which to base your new design can be daunting. The need to make the correct balance of price, performance, and power consumption has many implications.

Processing Power

The initial selection criterion is performance; microprocessor unit (MPU) offers more processing power than microcontroller unit (MCU). A broad comparison between devices can be made by comparing the quoted Dhrystone MIPS—millions of instructions per second.

For advanced mathematical applications, required processing power will be more; hence, MPU is selected in such situation. If the application is real time in nature, then MCU will be the ultimate choice; MCUs with timing deterministic processor core and flash memory make them suitable for applications that need functional safety.

Memory

The next criterion for selection of MCUs and MPUs is based on memory availability on chip or external memory. To store and execute the program, MCUs usually have on-chip flash memory. This memory is embedded on the chip; it is difficult to add more memory if the code size exceeds. Flash memory's advantage is faster access time. If the on-chip memory is not sufficient, one can swap the device in same family with more memory.

For program and data storage, MPUs use external memory which offers lot of flexibility. External NAND or serial flash is often used to store the program, then it is loaded into external DRAM; hence, the start-up process takes longer time than MCUs which have embedded on-chip memory.

Power and Price

MCUs are clear winners over MPU as far as power consumption is concern. They have various modules available inside it, and if you are not using them in your application, those modules just go in idle mode and save lot of power. Designing application by keeping power consumption to the lowest value with an MPU is difficult and tricky. There are some MPUs which come with modes consuming low power, but these are few and are complicated to achieve.

A very important aspect in the performance–power trade-off is price. Obviously, the price of an MCU or MPU will have a big role to play in whether it is selected or not. Here, MCU is the more cost-optimized solution, and also the low-power option. But, does it have the performance required? An MPU is generally used for high-performance applications, but can you afford it? Designer must find answer for all these questions in order to make the choice.

Time to Market

To sustain in the competitive market, tight time-to-market deadlines with simplicity of design are very important. MCU needs only one power rail section, whereas an MPU core needs several different voltage rails, the DDR, and other blocks, so additional power converters are required, which further adds complexity and cost of the design.

Last but not least, sometimes it is required to modify the existing product, and planning for the future use is important. In these cases, selecting a vendor with an extensive range of MCU and MPU products that are compatible will help maximize software reuse when the time comes.

So, the solution to this is **programmable logic devices (PLDs)** which offer the flexibility of redesigning and upgrade the entire designed product without changing the platform.

1.2 Family Tree of PLDs

PLDs are categorized as: simple programmable logic devices (SPLDs) and high-density programmable logic devices (HDPLDs). SPLDs are further divided in the programmable array logic (PAL) and programable logic array (PLA) architecture, while high-density PLDs (HDPLDs) include complex programable logic device (CPLD) and field programable gate array (FPGA). Figure 1.1 gives the PLD tree diagram which is self explanatory.

Simple Programmable Logic Devices

Devices under SPLD are PALs and PLA. PLAs and PALs have packing density up to several hundred gates. The basic PALs architecture of AND/OR is implemented in sum-of-product form (SOP) using Boolean equations. PLDs' advantage is that in order to get higher packaging density, it replaces small- to medium-scale integrated (SSI/MSI) circuits. Single PLD device replaces IC with hundreds of equivalent gate. Another advantage of SPLD is that they consume very less power, fast performance; turn-around time is faster because of very few interconnects between the chips; and they are also highly reliable in nature. SPLDs are categorized under bipolar and CMOS technology. CPLD devices are higher in density, but SPLDs still have the best performance and easy to use.