Embedded Processors: Characteristics and Trends

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Abstract

In this paper, we consider computational aspects of embedded systems and analyze briefly embedded processor characteristics, design styles, and project some possible design trends. We begin the presentation with a general discussion regarding embedded systems in general and provide a definition of embedded systems. We continue by describing embedded processor characteristics and discuss some future research directions.

1 Introduction

A technology turning point that made embedded systems an everyday reality has to be the advent of microprocessors. The technological developments that allowed single chip processors (microprocessors) made the embedded systems inexpensive and flexible. Consequently, microprocessor based embedded systems have been introduced into many new application areas. Currently, embedded programmable microprocessors in one form or another, from 8-bit micro–controllers to 32-bit digital signal processors and 64-bit RISC processors, are everywhere, in consumer electronic devices, home appliances, automobiles, network equipment, industrial control systems, etc. The employment of embedded processors appear to grow in an exponential curve. For example, Figure 1 shows marketing projections of shipments of embedded processors outpacing those of PC processors. It can be observed that in 1996, the sales of embedded processors was just a bit more than half of the sales of PC processors. In 1997, the sales of embedded systems already equaled that of PC processors and is showing a much higher growth rate. In contrast, PC processors are only showing a gradual growth.

Some of the driving forces behind the fast expansion of the embedded systems market relates to
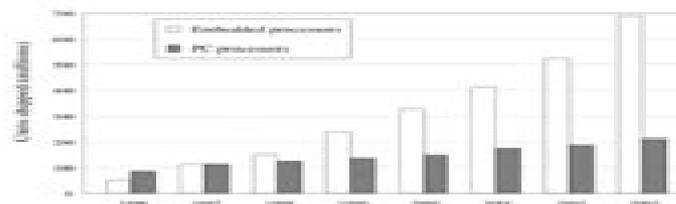

Figure 1: *Marketing projections. (from [1])*

the proliferation of computing technologies to traditionally non-computing domains, e.g., medical instrumentation, automotive industry, the fast advances in VLSI technologies, and the tendency to replace analog signal processing with digital signal processing.

In this paper, we discuss embedded systems in general and focus on the processors employed in such systems. This presentation is structured as follows. Section 2 discusses the distinction between an embedded system and systems in general. Furthermore, the section also formulate our definition of an embedded system. Section 3 explores the requirements of such systems and categorizes them. Section 4 presents a view of what we think are essential parts of an embedded system. Section 5 shifts our discussion to embedded processors by stating their characteristics. Section 6 concludes this presentation by stating some design trends of embedded processors.

2 On the Meaning of Embedded Systems

Generally speaking, digital systems can be designed for general purpose or for specific applications. General purpose systems are not customized for any specific application and they are charac-

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Reconfigurable Computing: Architectures, Tools, and Applications Roger Woods,2008-03-18 This book constitutes the refereed proceedings of the 4th International Workshop on Applied Reconfigurable Computing ARC 2008 held in London UK in March 2008 The 21 full papers and 14 short papers presented together with the abstracts of 3 keynote lectures were carefully reviewed and selected from 56 submissions The papers are organized in topical sections on programming and compilation DNA and string processing applications scientific applications reconfigurable computing hardware and systems image processing run time behavior instruction set extension as well as random number generation and financial computation **Embedded Processor Design Challenges** Ed F. Deprettere,Ju rgen Teich,Stamatis Vassiliadis,2002-03-13 This book presents a coherent introduction to and an overview of state of the art techniques in the design of complex embedded systems The volume brings together revised papers initially presented at a workshop held at Samos Greece in July and reviewed invited articles The papers are organized in topical sections on system level design and simulation compiler and mapping technology embedded processor and architectures and applications **Designing Embedded Processors** Jörg Henkel,Sri Parameswaran,2007-07-27 As we embrace the world of personal portable and perplexingly complex digital systems it has befallen upon the bewildered designer to take advantage of the available transistors to produce a system which is small fast cheap and correct yet possesses increased functionality Increasingly these systems have to consume little energy Designers are increasingly turning towards small processors which are low power and customize these processors both in software and hardware to achieve their objectives of a low power system which is verified and has short design turnaround times Designing Embedded Processors examines the many ways in which processor based systems are designed to allow low power devices It looks at processor design methods memory optimization dynamic voltage scaling methods compiler methods and multi processor methods Each section has an introductory chapter to give a breadth view and have a few specialist chapters in the area to give a deeper perspective The book provides a good starting point to engineers in the area and to research students embarking upon the exciting area of embedded systems and architectures **Customizable Embedded Processors** Paolo Ienne,Rainer Leupers,2006-08-30 Customizable processors have been described as the next natural step in the evolution of the microprocessor business a step in the life of a new technology where top performance alone is no longer sufficient to guarantee market success Other factors become fundamental such as time to market convenience energy efficiency and ease of customization This book is the first to explore comprehensively one of the most fundamental trends which emerged in the last decade to treat processors not as rigid fixed entities which designers include as is in their products but rather to build sound methodologies to tailor fit processors to the specific needs of such products This book addresses the goal of maintaining a very large family of processors with a wide range of features at a cost comparable to that of maintaining a single processor First book to present comprehensively the major ASIP design

methodologies and tools without any particular bias Written by most of the pioneers and top international experts of this young domain Unique mix of management perspective technical detail research outlook and practical implementation

Processor Description Languages Prabhat Mishra,Nikil Dutt,2011-07-28 Efficient design of embedded processors plays a critical role in embedded systems design Processor description languages and their associated specification exploration and rapid prototyping methodologies are used to find the best possible design for a given set of applications under various design constraints such as area power and performance This book is the first comprehensive survey of modern architecture description languages and will be an invaluable reference for embedded system architects designers developers and validation engineers Readers will see that the use of particular architecture description languages will lead to productivity gains in designing particular application specific types of embedded processors Comprehensive coverage of all modern architecture description languages use the right ADL to design your processor to fit your application Most up to date information available about each architecture description language from the developers save time chasing down reliable documentation Describes how each architecture desccription language enables key design automation tasks such as simulation synthesis and testing fit the ADL to your design cycle *Embedded Real-time Systemen* W.J. Toetenel,TU Delft, Faculty Information Technology and Systems, **Architecture Exploration for Embedded Processors with LISA** Andreas Hoffmann,Heinrich Meyr,Rainer Leupers,2013-06-29 Already today more than 90% of all programmable processors are employed in embedded systems This number is actually not surprising contemplating that in a typical home you might find one or two PCs equipped with high of embedded systems performance standard processors but probably dozens including electronic entertainment household and telecom devices each of them equipped with one or more embedded processors Moreover the elec tronic components of upper class cars incorporate easily over one hundred pro cessors Hence efficient embedded processor design is certainly an area worth looking at The question arises why programmable processors are so popular in embed ded system design The answer lies in the fact that they help to narrow the gap between chip capacity and designer productivity Embedded processors cores are nothing but one step further towards improved design reuse just along the lines of standard cells in logic synthesis and macrocells in RTL synthesis in earlier times of IC design Additionally programmable processors permit to migrate functionality from hardware to software resulting in an even improved reuse factor as well as greatly increased flexibility **Advanced Memory Optimization Techniques for Low-Power Embedded Processors** Manish Verma,Peter Marwedel,2007-06-20 In a relatively short span of time computers have evolved from huge mainframes to small and elegant desktop computers and now to low power ultra portable handheld devices Witheachpassinggeneration computersconsistingofprocessors memoriesandperipherals becamesmallerandfaster Forexample the rstcommercialcomputerUNIVACIcosted 1 million dollars occupied 943 cubic feet space and could perform 1 905 operations per second 94 Now a processor present in an electric shaver easily outperforms the early mainframe

computers The miniaturization is largely due to the efforts of engineers and scientists that made the expeditious progress in the microelectronic technologies possible According to Moore s Law 90 the advances in technology allow us to double the number of transistors on a single silicon chip every 18 months This has lead to an exponential increase in the number of transistors on a chip from 2 300 in an Intel 4004 to 42 millions in Intel Itanium processor 55 Moore s Law has withstood for 40 years and is predicted to remain valid for at least another decade 91 Notonlytheminiaturizationanddramaticperformanceimprovementbutalsothesign icantdropinthepriceofprocessors hasleadtosituationwheretheyarebeingintegratedinto products such as cars televisions and phones which are not usually associated with c puters This new trend has also been called the disappearing computer where the computer does not actually disappear but it is everywhere 85 Digital devices containing processors now constitute a major part of our daily lives Asmalllistofsuchdevicesincludesmicrowaveovens televisionsets mobilephones digital cameras MP3 players and cars Whenever a system comprises of information processingdigitaldevicestocontrolortoaugmentitsfunctionality suchasystemistermedanembedded system Therefore all the above listed devices can be also classi ed as embedded systems

Harnessing Performance Variability in Embedded and High-performance Many/Multi-core Platforms William Fornaciari,Dimitrios Soudris,2018-10-23 This book describes the state of the art of industrial and academic research in the architectural design of heterogeneous multi many core processors The authors describe methods and tools to enable next generation embedded and high performance heterogeneous processors to confront cost effectively the inevitable variations by providing Dependable Performance correct functionality and timing guarantees throughout the expected lifetime of a platform under thermal power and energy constraints Various aspects of the reliability problem are discussed at both the circuit and architecture level the intelligent selection of knobs and monitors in multicore platforms and systematic design methodologies The authors demonstrate how new techniques have been applied in real case studies from different applications domain and report on results and conclusions of those experiments Enables readers to develop performance dependable heterogeneous multi many core architectures Describes system software designs that support high performance dependability requirements Discusses and analyzes low level methodologies to tradeoff conflicting metrics i e power performance reliability and thermal management Includes new application design guidelines to improve performance dependability **Domain-Specific Processors** Shuvra S. Bhattacharyya,Ed F. Deprettere,Jörgen Teich,2003-11-11 Ranging from low level application and architecture optimizations to high level modeling and exploration concerns this authoritative reference compiles essential research on various levels of abstraction appearing in embedded systems and software design It promotes platform based design for improved system implementation and modeling and enhanced *Code Generation for Embedded Processors* Peter Marwedel,Gert Goossens,2013-03-14 Modern electronics is driven by the explosive growth of digital communications and multi media technology A basic challenge is to design first time right complex digital systems

that meet stringent constraints on performance and power dissipation In order to combine this growing system complexity with an increasingly short time to market new system design technologies are emerging based on the paradigm of embedded programmable processors This concept introduces modularity flexibility and re use in the electronic system design process However its success will critically depend on the availability of efficient and reliable CAD tools to design programme and verify the functionality of embedded processors Recently new research efforts emerged on the edge between software compilation and hardware synthesis to develop high quality code generation tools for embedded processors Code Generation for Embedded Systems provides a survey of these new developments Although not limited to these targets the main emphasis is on code generation for modern DSP processors Important themes covered by the book include the scope of general purpose versus application specific processors machine code quality for embedded applications retargetability of the code generation process machine description formalisms and code generation methodologies Code Generation for Embedded Systems is the essential introduction to this fast developing field of research for students researchers and practitioners alike

Ultra-Low Energy Domain-Specific Instruction-Set Processors Francky Catthoor,Praveen Raghavan,Andy Lambrechts,Murali Jayapala,Angeliki Kritikakou,Javed Absar,2010-08-05 Modern consumers carry many electronic devices like a mobile phone digital camera GPS PDA and an MP3 player The functionality of each of these devices has gone through an important evolution over recent years with a steep increase in both the number of features as in the quality of the services that they provide However providing the required compute power to support an uncompromised combination of all this functionality is highly non trivial Designing processors that meet the demanding requirements of future mobile devices requires the optimization of the embedded system in general and of the embedded processors in particular as they should strike the correct balance between flexibility energy efficiency and performance In general a designer will try to minimize the energy consumption as far as needed for a given performance with a sufficient flexibility However achieving this goal is already complex when looking at the processor in isolation but in reality the processor is a single component in a more complex system In order to design such complex system successfully critical decisions during the design of each individual component should take into account effect on the other parts with a clear goal to move to a global Pareto optimum in the complete multi dimensional exploration space In the complex global design of battery operated embedded systems the focus of Ultra Low Energy Domain Specific Instruction Set Processors is on the energy aware architecture exploration of domain specific instruction set processors and the co optimization of the datapath architecture foreground memory and instruction memory organisation with a link to the required mapping techniques or compiler steps at the early stages of the design By performing an extensive energy breakdown experiment for a complete embedded platform both energy and performance bottlenecks have been identified together with the important relations between the different components Based on this knowledge architecture extensions are proposed for all the bottlenecks *Code Generation and Optimization for Embedded*

Processors M. Milan,2002   Embedded Processor Design Challenges Ed F. Deprettere,Stamatis Vassiliadis,2014-01-15
    Embedded, Everywhere National Research Council,Division on Engineering and Physical Sciences,Computer Science and Telecommunications Board,Committee on Networked Systems of Embedded Computers,2001-09-18 Advances in the miniaturization and networking of microprocessors promise a day when networked computers are embedded throughout the everyday world However our current understanding of what such systems would be like is insufficient to bring the promise to reality Embedded Everywhere explores the potential of networked systems of embedded computers and the research challenges arising from embedding computation and communications technology into a wide variety of applications from precision agriculture to automotive telematics to defense systems It describes how these emerging networks operate under unique constraints not present in more traditional distributed systems such as the Internet It articulates how these networks will have to be dynamically adaptive and self configuring and how new models for approaching programming and computation are necessary Issues relating to trustworthiness security safety reliability usability and privacy are examined in light of the ubiquitous nature of these systems A comprehensive systems oriented research agenda is presented along with recommendations to major federal funding agencies   Benchmark Characterization of Embedded Processors ,2004 The design of a processor is an iterative process with many cycles of simulation performance analysis and subsequent changes The inputs to these cycles of simulations are generally a selected subset of standard benchmarks To aid in reducing the number of cycles involved in design one can characterize these selected benchmarks and use those characteristics to hit at a good initial design that will converge faster Methods and systems to characterize benchmarks for normal processors are designed and implemented This thesis extends these approaches and defines an abstract system to characterize benchmarks for embedded processors taking into consideration the architectural requirements power constraints and code compressibility To demonstrate this method around 25 benchmarks are characterized 10 from SPEC and 15 from standard embedded benchmark suites Mediabench and Netbench and compared Moreover the similarities between these benchmarks are also analyzed and presented   Real-time Constrained Reconfigurable Communication Between Embedded Processors Jeroen Anton Johan Leijten,1998   *Modeling and Description of Embedded Processors for the Development of Software Tools* Wei Qin,2004

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