



Advanced Arithmetic for the Digital Computer, Design of Arithmetic Units

Ulrich Kulisch

Abstract

Abstract Advances in computer technology are now so profound that the arithmetic capability and repertoire of computers can and should be expanded. Nowadays the elementary floating-point operations $+$, $-$, \times , $/$ give computed results that coincide with the rounded exact result for any operands. Advanced computer arithmetic extends this accuracy requirement to all operations in the usual product spaces of computation: the real and complex vector spaces as well as their interval correspondents. This enhances the mathematical power of the digital computer considerably. A new computer operation, the scalar product, is fundamental to the development of advanced computer arithmetic.

This paper studies the design of arithmetic units for advanced computer arithmetic. Scalar product units are developed for different kinds of computers like personal computers, workstations, mainframes, super computers or digital signal processors. The new expanded computational capability is gained at modest cost. The units put a methodology into modern computer hardware which was available on old calculators before the electronic computer entered the scene. In general the new arithmetic units increase both the speed of computation as well as the accuracy of the computed result. The circuits developed in this paper show that there is no way to compute an approximation of a scalar product faster than the correct result.

A collection of constructs in terms of which a source language may accommodate advanced computer arithmetic is described in the paper. The development of programming languages in the context of advanced computer arithmetic is reviewed. The simulation of the accurate scalar product on existing, conventional processors is discussed. Finally the theoretical foundation of advanced computer arithmetic is reviewed and a comparison with other approaches to achieving higher accuracy in computation is given. Shortcomings of existing processors and standards are discussed.

Advanced Arithmetic For The Digital Computer Design Of Arithmetic Units

Ulrich Kulisch



Advanced Arithmetic For The Digital Computer Design Of Arithmetic Units:

Advanced Arithmetic for the Digital Computer Ulrich W. Kulisch, 2012-09-07 The number one requirement for computer arithmetic has always been speed It is the main force that drives the technology With increased speed larger problems can be attempted To gain speed advanced processors and programming languages offer for instance compound arithmetic operations like matmul and dotproduct But there is another side to the computational coin the accuracy and reliability of the computed result Progress on this side is very important if not essential Compound arithmetic operations for instance should always deliver a correct result The user should not be obliged to perform an error analysis every time a compound arithmetic operation implemented by the hardware manufacturer or in the programming language is employed This treatise deals with computer arithmetic in a more general sense than usual Advanced computer arithmetic extends the accuracy of the elementary floating point operations for instance as defined by the IEEE arithmetic standard to all operations in the usual product spaces of computation the complex numbers the real and complex intervals and the real and complex vectors and matrices and their interval counterparts The implementation of advanced computer arithmetic by fast hardware is examined in this book Arithmetic units for its elementary components are described It is shown that the requirements for speed and for reliability do not conflict with each other Advanced computer arithmetic is superior to other arithmetic with respect to accuracy costs and speed

Advanced Arithmetic for the Digital Computer Ulrich Kulisch, 1998

Advanced Arithmetic for the Digital Computer Ulrich Kulisch, 2014-01-15

Design of Arithmetic Units for Digital Computers GOSLING, 2013-11-11 The original motivation for the development of digital computers was to make it possible to perform calculations that were too large to be attempted by a human being without serious likelihood of error Once the users found that they could achieve their initial aims they then wanted to go into greater detail and to solve still bigger problems so that the demand for extra computing power has continued unabated and shows no sign of slackening This book is an attempt to describe some of the more important techniques used today or likely to be used in the near future to perform arithmetic within the computing machine There are at present few books in this field Most books on computer design cover the more elementary methods and some go into detail on one or two more ambitious units Space does not allow more In this text the aim has been to fill this gap in the literature In selecting the topics to be covered there have been two main aims first to deal with the basic procedures of arithmetic and then to carry on to the design of more powerful units second to maintain a strictly practical approach The number of mathematical formulae has been kept to a minimum and the more complex ones have been eliminated since they merely serve to obscure the essential principles

Advanced Arithmetic for the Digital Computer Ulrich Kulisch, 2001

Algorithms and Design Methods for Digital Computer Arithmetic Behrooz Parhami, 2012 Ideal for graduate and senior undergraduate courses in computer arithmetic and advanced digital design

Computer Arithmetic Algorithms and Hardware Designs Second Edition provides a balanced comprehensive treatment of

computer arithmetic It covers topics in arithmetic unit design and circuit implementation that complement the architectural and algorithmic speedup techniques used in high performance computer architecture and parallel processing Using a unified and consistent framework the text begins with number representation and proceeds through basic arithmetic operations floating point arithmetic and function evaluation methods Later chapters cover broad design and implementation topics including techniques for high throughput low power fault tolerant and reconfigurable arithmetic An appendix provides a historical view of the field and speculates on its future An indispensable resource for instruction professional development and research **Computer Arithmetic Algorithms and Hardware Designs** Second Edition combines broad coverage of the underlying theories of computer arithmetic with numerous examples of practical designs worked out examples and a large collection of meaningful problems This second edition includes a new chapter on reconfigurable arithmetic in order to address the fact that arithmetic functions are increasingly being implemented on field programmable gate arrays FPGAs and FPGA like configurable devices Updated and thoroughly revised the book offers new and expanded coverage of saturating adders and multipliers truncated multipliers fused multiply add units overlapped quotient digit selection bipartite and multipartite tables reversible logic dot notation modular arithmetic Montgomery modular reduction division by constants IEEE floating point standard formats and interval arithmetic Readership Graduate and senior undergraduate courses in computer arithmetic and advanced digital design

Computer Arithmetic and Validity Ulrich Kulisch, 2013-04-30 This is the revised and extended second edition of the successful basic book on computer arithmetic It is consistent with the newest recent standard developments in the field The book shows how the arithmetic and mathematical capability of the digital computer can be enhanced in a quite natural way The work is motivated by the desire and the need to improve the accuracy of numerical computing and to control the quality of the computed results validity The accuracy requirements for the elementary floating point operations are extended to the customary product spaces of computations including interval spaces The mathematical properties of these models are extracted into an axiomatic approach which leads to a general theory of computer arithmetic Detailed methods and circuits for the implementation of this advanced computer arithmetic on digital computers are developed in part two of the book Part three then illustrates by a number of sample applications how this extended computer arithmetic can be used to compute highly accurate and mathematically verified results The book can be used as a high level undergraduate textbook but also as reference work for research in computer arithmetic and applied mathematics

Advanced Computer Arithmetic Design Michael J. Flynn, Stuart F. Oberman, 2001 Innovative techniques and cutting edge research in computer arithmetic design Computer arithmetic is a fundamental discipline that drives many modern digital technologies High performance VLSI implementations of 3 D graphics encryption streaming digital audio and video and signal processing all require fast and efficient computer arithmetic algorithms The demand for these fast implementations has led to a wealth of new research in innovative techniques and designs **Advanced Computer Arithmetic**

Design is the result of ten years of effort at Stanford University under the Sub Nanosecond Arithmetic Processor SNAP project which author Michael Flynn directs. Written with computer designers and researchers in mind, this volume focuses on design rather than on other aspects of computer arithmetic such as number systems representation or precision. Each chapter begins with a review of conventional design approaches, analyzes the possibilities for improvement, and presents new research that advances the state of the art. The authors present new data in these vital areas: Addition and the Ling adder; Improvements to floating point addition; Encoding to reduce execution times for multiplication; The effects of technology scaling on multiplication; Techniques for floating point division; Approximation techniques for high level functions such as square root, logarithms, and trigonometric functions; Assessing cost performance of arithmetic units; Clocking to increase computer operation frequency; New implementation of continued fractions to the approximation of functions. This volume presents the results of a decade's research in innovative and progressive design techniques. Covering all the most important research topics in the field, *Advanced Computer Arithmetic Design* is the most up to date and comprehensive treatment of new research currently available.

Advanced Avionic Digital Computer; Arithmetic and Control Unit Design Study
Noel A. Boehmer, Charles A. Pullen, Donald D. Achterberg, Melvin M. Cutler, Floyd D. Erwin, HUGHES AIRCRAFT CO CULVER CITY CA., 1970. Design tradeoffs leading to recommended baselines are developed for the arithmetic unit and control unit of the Advanced Avionic Digital Computer AADC which is intended for wide applicability across the spectrum of 1975-1985 Naval avionic systems. Baseline arithmetic and control units operating together with a 150 ns cycle time task memory exceed target execution speed goals of 2 million instructions per second while the extreme application flexibility fundamental to AADC effectivity is emphasized. Assuming 3 ns logic gate delay, each unit requires one LSI wafer of 10,000 gate complexity. In addition, the control unit requires 51,000 bits of microprogram memory and the arithmetic unit requires 128,000 bits of microprogram memory assuming 50 ns cycle time. Author.

Computer Arithmetic Behrooz Parhami, 2010. Ideal for graduate and senior undergraduate courses in computer arithmetic and advanced digital design. *Computer Arithmetic: Algorithms and Hardware Designs*, Second Edition, provides a balanced, comprehensive treatment of computer arithmetic. It covers topics in arithmetic unit design and circuit implementation that complement the architectural and algorithmic speedup techniques used in high performance computer architecture and parallel processing. Using a unified and consistent framework, the text begins with number representation and proceeds through basic arithmetic operations, floating point arithmetic, and function evaluation methods. Later chapters cover broad design and implementation topics including techniques for high throughput, low power, fault tolerant, and reconfigurable arithmetic. An appendix provides a historical view of the field and speculates on its future. An indispensable resource for instruction, professional development, and research.

Computer Arithmetic: Algorithms and Hardware Designs, Second Edition, combines broad coverage of the underlying theories of computer arithmetic with numerous examples of practical designs, worked out examples, and a large collection of

meaningful problems This second edition includes a new chapter on reconfigurable arithmetic in order to address the fact that arithmetic functions are increasingly being implemented on field programmable gate arrays FPGAs and FPGA like configurable devices Updated and thoroughly revised the book offers new and expanded coverage of saturating adders and multipliers truncated multipliers fused multiply add units overlapped quotient digit selection bipartite and multipartite tables reversible logic dot notation modular arithmetic Montgomery modular reduction division by constants IEEE floating point standard formats and interval arithmetic

Scientific and Technical Aerospace Reports ,1965 **Arithmetic and Logic in Computer Systems** Mi Lu,2005-02-18 Arithmetic and Logic in Computer Systems provides a useful guide to a fundamental subject of computer science and engineering Algorithms for performing operations like addition subtraction multiplication and division in digital computer systems are presented with the goal of explaining the concepts behind the algorithms rather than addressing any direct applications Alternative methods are examined and explanations are supplied of the fundamental materials and reasoning behind theories and examples No other current books deal with this subject and the author is a leading authority in the field of computer arithmetic The text introduces the Conventional Radix Number System and the Signed Digit Number System as well as Residue Number System and Logarithmic Number System This book serves as an essential up to date guide for students of electrical engineering and computer and mathematical sciences as well as practicing engineers and computer scientists involved in the design application and development of computer arithmetic units

Digital Computer Arithmetic Joseph Cavanagh,1984 Space Communications- Theory and Applications. Volume 3- Information Processing and Advanced Techniques a Bibliography, 1958 - 1963 ,1965 **Illinois Technograph** ,1963 **Computer Literature Bibliography: 1946-1963** W. W. Youden,1965 *Advanced Digital Logic Design* Sunggu Lee,2006 This textbook is intended to serve as a practical guide for the design of complex digital logic circuits such as digital control circuits network interface circuits pipelined arithmetic units and RISC microprocessors It is an advanced digital logic design textbook that emphasizes the use of synthesizable Verilog code and provides numerous fully worked out practical design examples including a Universal Serial Bus interface a pipelined multiply accumulate unit and a pipelined microprocessor for the ARM THUMB architecture

The Logical Design of the Arithmetic Unit of a Digital Computer Moshe Mano,1958 *NBS Special Publication* ,1965 National Bureau of Standards Miscellaneous Publication ,1965

The Enigmatic Realm of **Advanced Arithmetic For The Digital Computer Design Of Arithmetic Units**: Unleashing the Language is Inner Magic

In a fast-paced digital era where connections and knowledge intertwine, the enigmatic realm of language reveals its inherent magic. Its capacity to stir emotions, ignite contemplation, and catalyze profound transformations is nothing in short supply of extraordinary. Within the captivating pages of **Advanced Arithmetic For The Digital Computer Design Of Arithmetic Units** a literary masterpiece penned by a renowned author, readers attempt a transformative journey, unlocking the secrets and untapped potential embedded within each word. In this evaluation, we shall explore the book's core themes, assess its distinct writing style, and delve into its lasting effect on the hearts and minds of those that partake in its reading experience.

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