Advanced Arithmetic for the Digital Computer, Design of Arithmetic Units

Ulrich Kulisch

Abstract

AbstractAdvances 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.
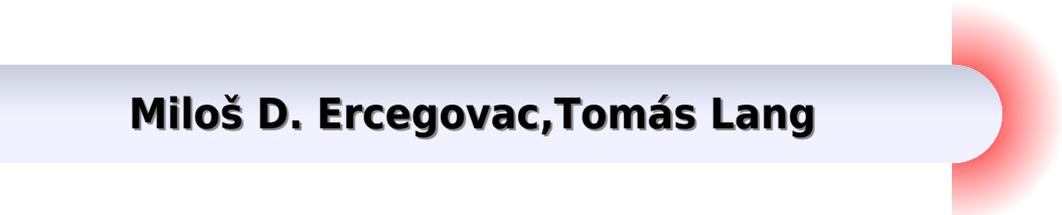
This paper studies the design of arithmetic units for advanced computer arithmetic. Scalar product units are developed for different kinds of computers like personal computers, workstations, mainframes, super computers or digital signal processors. The new expanded computational capability is gained 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.

Digital Computer Arithmetic

Miloš D. Ercegovac, Tomás Lang

Digital Computer Arithmetic:
    Digital Computer Arithmetic Joseph Cavanagh,1984   *Digital Computer Arithmetic* Joseph J. F. Cavanagh,1984
    Digital Arithmetic Miloš D. Ercegovac,Tomás Lang,2003-09-15 Digital arithmetic plays an important role in the design of general purpose digital processors and of embedded systems for signal processing graphics and communications In spite of a mature body of knowledge in digital arithmetic each new generation of processors or digital systems creates new arithmetic design problems Designers researchers and graduate students will find solid solutions to these problems in this comprehensive state of the art exposition of digital arithmetic Ercegovac and Lang two of the field s leading experts deliver a unified treatment of digital arithmetic tying underlying theory to design practice in a technology independent manner They consistently use an algorithmic approach in defining arithmetic operations illustrate concepts with examples of designs at the logic level and discuss cost performance characteristics throughout Students and practicing designers alike will find Digital Arithmetic a definitive reference and a consistent teaching tool for developing a deep understanding of the arithmetic style of algorithms and designs Guides readers to develop sound solutions avoid known mistakes and repeat successful design decisions Presents comprehensive coverage3 4from fundamental theories to current research trends Written in a clear and engaging style by two masters of the field Concludes each chapter with in depth discussions of the key literature Includes a full set of over 250 exercises   **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 pro gramming 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   <u>Design of Arithmetic Units for Digital Computers</u> 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 **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 Algorithms** Israel Koren,2018-10-08 This text explains the fundamental principles of algorithms available for performing arithmetic operations on digital computers These include basic arithmetic operations like addition subtraction multiplication and division in fixed point and floating point number systems as well as more complex operations such as square root extraction and evaluation of exponential logarithmic and trigonometric functions The algorithms described are

independent of the particular technology employed for their implementation   Digital Computer Arithmetic Techniques Larry Reid Kizer,1971   **Advanced Arithmetic for the Digital Computer** Ulrich Kulisch,2014-01-15   **Computer Arithmetic** Earl E Swartzlander,Carl E Lemonds,2015-02-12 Computer Arithmetic Volume III is a compilation of key papers in computer arithmetic on floating point arithmetic and design The intent is to show progress evolution and novelty in the area of floating point arithmetic This field has made extraordinary progress since the initial software routines on mainframe computers have evolved into hardware implementations in processors spanning a wide range of performance Nevertheless these papers pave the way to the understanding of modern day processors design where computer arithmetic are supported by floating point units The goal of Volume III is to collect the defining document for floating point arithmetic and many of the key papers on the implementation of both binary and decimal floating point arithmetic into a single volume Although fewer than forty papers are included their reference lists will direct the interested reader to other excellent work that could not be included here Volume III is specifically oriented to the needs of designers and users of both general purpose computers and special purpose digital processors The book should also be useful to systems engineers computer architects and logic designers It is also intended to serve as a primary text for a course on floating point arithmetic as well as a supplementary text for courses in digital arithmetic and high speed signal processing This volume is part of a 3 volume set Computer Arithmetic Volume I Computer Arithmetic Volume II Computer Arithmetic Volume III The full set is available for sale in a print only version Contents OverviewFloating Point AdditionFloating Point MultiplicationRoundingFused Multiply AddFloating Point DivisionElementary FunctionsDecimal Floating Point Arithmetic Readership Graduate students and research professionals interested in computer arithmetic Key Features The papers that are included cover the key concepts needed to develop efficient fast small and low power floating point processing unitsThe papers include presentations by the initial developers in their own words to better explain the basic techniquesIncludes five papers on decimal floating point arithmetic which has been added to the IEEE standardKeywords Floating Point Addition Floating Point Multiplication Floating Point Division Decimal Floating Point Arithmetic   *Computer Arithmetic* Earl E Swartzlander,2015-03-17 The book provides many of the basic papers in computer arithmetic These papers describe the concepts and basic operations in the words of the original developers that would be useful to the designers of computers and embedded systems Although the main focus is on the basic operations of addition multiplication and division advanced concepts such as logarithmic arithmetic and the calculations of elementary functions are also covered This volume is part of a 3 volume set Computer Arithmetic Volume I Computer Arithmetic Volume II Computer Arithmetic Volume III The full set is available for sale in a print only version Contents OverviewAdditionParallel Prefix AdditionMulti Operand AdditionMultiplicationDivisionLogarithmsElementary FunctionsFloating Point Arithmetic Readership Graduate students and research professionals interested in computer arithmetic Key Features It reprints the classic papersIt covers the basic

arithmetic operationsIt does this in the words of the creatorsKeywords Computer Arithmetic Adders Parallel Prefix Adders Multi operand Adders Multipliers Dividers Logarithmic Arithmetic Elementary Function Evaluation   **The Logic of Computer Arithmetic** Ivan Flores,1963 This book is a complete exhaustive yet readable exposition of high speed binary digital computer arithmetic hardware and its rationale Preface   **Computer Arithmetic** F. H. George,2014-05-09 Computer Arithmetic provides information pertinent to the fundamental aspects of a digital computer This book discusses how the control unit uses the arithmetic unit to produce under commands the answers asked by the user Organized into four chapters this book begins with an overview of the binary code and provides a preview of the use of other arithmetic codes outside the computer This text then explains in detail the codes employed in the representation of numbers inside the computer Other chapters consider the number systems as well as other related matters to be able to understand computer arithmetic This book discusses as well the signed numbers and their conversations as well as the problems of scaling The final chapter deals with the methods of fixed and floating point arithmetic rounding off and overflow This book is a valuable resource for sixth form as well as university students who are interested in arithmetic codes   **Digital Computer Arithmetic Datapath Design Using Verilog HDL** James E. Stine,2004 Verilog HDL is a Hardware Description Language used for simulating digital systems including Very Large Scale Integration VLSI systems This text describes the use of Verilog in creating designs used for design validation at the structural level This is done largely through the presentation of Verilog datapath design implementations and accompanying theoretical explanation The CD ROM contains the computer files discussed in the text Annotation 2004 Book News Inc Portland OR booknews com   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 Structure and Design** R. Townsend,2014-05-20 Digital Computer Structure and Design Second Edition discusses switching theory counters sequential circuits number representation and arithmetic functions The book also describes computer memories the processor data flow system of the processor the processor control system and the input output system Switching theory which is purely a mathematical concept centers on the properties of interconnected

networks of gates The theory deals with binary functions of 1 and 0 which can change instantaneously from one to the other without intermediate values The binary number system is used in computer arithmetic and other operations due to its simplicity that can be easily adopted in device parameters These operations involve only two levels the on or off positions which also offer maximum immunity to noise or circuit interference The binary system is a very efficient way to represent numbers or to store data When the computer uses this system the clock cycle of the processor determines or divides the cycles for each sub operation into steps A master timing counter defines each of these steps and synchronizes them avoid data loss or mix ups After the sub operation has been completed the monitor will display the result Programmers computer engineers computer instructors and students of computer science will find the book highly useful   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   *Arithmetic Operations in Digital Computers* Richard Kohler Richards,2013-09   **Instructor's Manual For Computer Arithmetic** Behrooz Parhami,Professor in the Department of Electrical and Computer Engineering Behrooz Parhami,2000-01-15 This title provides a view of computer arithmetic covering 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   Computer Arithmetic Systems Amos R. Omondi,1994 Aimed at digital designers computer hardware designers and computer architects this title deals with algorithms and hardware for operations in conventional fixed point number systems algorithms and hardware for operations in floating point number systems and unconventional number systems

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