

# **Place Coding in Analog VLSI**

**A Neuromorphic Approach to  
Computation**

**Oliver Landolt**

**Foreword by Eric Vittoz**

**Kluwer Academic Publishers**

# Place Coding In Analog Vlsi A Neuromorphic Approach To Computation

**Robert A. Wilson, Frank C. Keil**



## **Place Coding In Analog Vlsi A Neuromorphic Approach To Computation:**

*Place Coding in Analog VLSI* Oliver Landolt, 1998-07-31 Microelectronics have been bio inspired by the human brain to devise a new way via topological maps to represent and process data In the world of fuzzy logic and artificial neural networks Landolt CSEM SA Neuchatel Switzerland tours the place encoding of numbers by their location in a spot of cellular activity the concepts circuits some perspectives on and extensions of the concepts to difficult computational problems The theoretical portion defines the relationships between an activity spot on the map and the value it represents and between two or more maps created by a synthesis of circuits The validity of the concept for engineers is supported by examples of working VLSI chips Annotation copyrighted by Book News Inc Portland OR [Place Coding in Analog VLSI](#) Oliver Landolt, 2012-12-06 Neurobiology research suggests that information can be represented by the location of an activity spot in a population of cells place coding and that this information can be processed by means of networks of interconnections Place Coding in Analog VLSI defines a representation convention of similar flavor intended for analog integrated circuit design It investigates its properties and suggests ways to build circuits on the basis of this coding scheme In this electronic version of place coding numbers are represented by the state of an array of nodes called a map and computation is carried out by a network of links In the simplest case a link is just a wire connecting a node of an input map to a node of an output map In other cases a link is an elementary circuit cell Networks of links are somewhat reminiscent of look up tables in that they hardwire an arbitrary function of one or several variables Interestingly these structures are also related to fuzzy rules as well as some types of artificial neural networks The place coding approach provides several substantial benefits over conventional analog design Networks of links can be synthesized by a simple procedure whatever the function to be computed Place coding is tolerant to perturbations and noise in current mode implementations Tolerance to noise implies that the fundamental power dissipation limits of conventional analog circuits can be overcome by using place coding The place coding approach is illustrated by three integrated circuits computing non linear functions of several variables The simplest one is made up of 80 links and achieves submicrowatt power consumption in continuous operation The most complex one incorporates about 1800 links for a power consumption of 6 milliwatts and controls the operation of an active vision system with a moving field of view Place Coding in Analog VLSI is primarily intended for researchers and practicing engineers involved in analog and digital hardware design especially bio inspired circuits The book is also a valuable reference for researchers and students in neurobiology neuroscience robotics fuzzy logic and fuzzy control [MicroNeuro'99 : Proceedings of the Seventh International Conference on Microelectronics for Neural, Fuzzy and Bio-inspired Systems : April 7-9, 1999, Granada, Spain](#) Universidad de Granada, 1999 Organized by the U of Granada the April 1999 conference focused on applications of bio inspired microelectronic circuits and systems Published as extended papers the contributions represent five invited talks on various phenomena to emerging technology advances a demonstration of the autonomic **Neural Computation in Embodied**

## **Closed-Loop Systems for the Generation of Complex Behavior: From Biology to Technology** Poramate

Manoonpong, Christian Tetzlaff, 2018-10-11 How can neural and morphological computations be effectively combined and realized in embodied closed loop systems e.g. robots such that they can become more like living creatures in their level of performance? Understanding this will lead to new technologies and a variety of applications. To tackle this research question here we bring together experts from different fields including Biology, Computational Neuroscience, Robotics and Artificial Intelligence to share their recent findings and ideas and to update our research community. This eBook collects 17 cutting edge research articles covering neural and morphological computations as well as the transfer of results to real world applications like prosthesis and orthosis control and neuromorphic hardware implementation. **Neuromorphic Systems:**

**Engineering Silicon From Neurobiology** Alister Hamilton, Leslie S. Smith, 1998-05-13 Neuromorphic systems are implementations in silicon of sensory and neural systems whose architecture and design are based on neurobiology. This growing area offers exciting possibilities such as sensory systems that can compete with human senses and pattern recognition systems that can run in real time. It is at the intersection of neurophysiology, computer science and electrical engineering. This book brings together recent developments in Europe and the US so that researchers in both academia and industry can find out about the state of the art. As well as elementary material on what neuromorphic systems are and why they are growing in importance, the book contains details of current work. There are articles on aspects of implementing sensory neuromorphic systems and also on neuromorphic hardware. **American Book Publishing Record**, 1998

Cellular Neural Networks and Analog VLSI Leon Chua, Glenn Gulak, Edmund Pierzchala, Ángel

Rodríguez-Vázquez, 2013-03-09 Cellular Neural Networks and Analog VLSI brings together in one place important contributions and up to date research results in this fast moving area. Cellular Neural Networks and Analog VLSI serves as an excellent reference providing insight into some of the most challenging research issues in the field. **Learning in**

**Energy-Efficient Neuromorphic Computing: Algorithm and Architecture Co-Design** Nan Zheng, Pinaki

Mazumder, 2019-10-18 Explains current co design and co optimization methodologies for building hardware neural networks and algorithms for machine learning applications. This book focuses on how to build energy efficient hardware for neural networks with learning capabilities and provides co design and co optimization methodologies for building hardware neural networks that can learn. Presenting a complete picture from high level algorithm to low level implementation details, Learning in Energy Efficient Neuromorphic Computing: Algorithm and Architecture Co Design also covers many fundamentals and essentials in neural networks e.g. deep learning as well as hardware implementation of neural networks. The book begins with an overview of neural networks. It then discusses algorithms for utilizing and training rate based artificial neural networks. Next comes an introduction to various options for executing neural networks ranging from general purpose processors to specialized hardware from digital accelerator to analog accelerator. A design example on building energy efficient accelerator

for adaptive dynamic programming with neural networks is also presented An examination of fundamental concepts and popular learning algorithms for spiking neural networks follows that along with a look at the hardware for spiking neural networks Then comes a chapter offering readers three design examples two of which are based on conventional CMOS and one on emerging nanotechnology to implement the learning algorithm found in the previous chapter The book concludes with an outlook on the future of neural network hardware Includes cross layer survey of hardware accelerators for neuromorphic algorithms Covers the co design of architecture and algorithms with emerging devices for much improved computing efficiency Focuses on the co design of algorithms and hardware which is especially critical for using emerging devices such as traditional memristors or diffusive memristors for neuromorphic computing Learning in Energy Efficient Neuromorphic Computing Algorithm and Architecture Co Design is an ideal resource for researchers scientists software engineers and hardware engineers dealing with the ever increasing requirement on power consumption and response time It is also excellent for teaching and training undergraduate and graduate students about the latest generation neural networks with powerful learning capabilities *Principles of Neural Coding* Rodrigo Quian Quiroga, Stefano Panzeri, 2013-05-06

Understanding how populations of neurons encode information is the challenge faced by researchers in the field of neural coding Focusing on the many mysteries and marvels of the mind has prompted a prominent team of experts in the field to put their heads together and fire up a book on the subject Simply titled *Principles of Neural Coding* this book **Neuromorphic Photonics** Paul R. Prucnal, Bhavin J. Shastri, 2017-05-08 This book sets out to build bridges between the domains of photonic device physics and neural networks providing a comprehensive overview of the emerging field of neuromorphic photonics It includes a thorough discussion of evolution of neuromorphic photonics from the advent of fiber optic neurons to today's state of the art integrated laser neurons which are a current focus of international research Neuromorphic Photonics explores candidate interconnection architectures and devices for integrated neuromorphic networks along with key functionality such as learning It is written at a level accessible to graduate students while also intending to serve as a comprehensive reference for experts in the field The Making of a Neuromorphic Visual System Christoph Rasche, 2005-12-06 This book presents an approach to the construction of a visual system which is behaviorally computationally and neurally motivated The goal is to characterize the process of visual categorization and to find a suitable representation format that can successfully deal with the structural variability existent within visual categories The book reviews past and existent theories of visual object and shape recognition in the fields of computer vision neuroscience and psychology The entire range of computations is discussed as are region based approaches and are modeled with wave propagating networks A completely novel shape recognition architecture is proposed that can recognize simple shapes under various degraded conditions It is discussed how such networks can be used for constructing basic level object representations It is envisioned how those networks can be implemented using the method of neuromorphic engineering Neuromorphic Intelligence Shuangming Yang, Badong

Chen,2024-05-14 This book provides a valuable resource on the design of neuromorphic intelligence which serves as a computational foundation for building compact and low power brain inspired intelligent systems The book introduces novel spiking neural network learning algorithms including spike based learning based on the multi compartment model and spike based learning with information theory These offer important insights and academic value for readers to grasp the latest advances in neural inspired learning Additionally the book presents insights and approaches to the design of scalable neuromorphic architectures which are crucial foundations for achieving highly cognitive and energy efficient computing systems Furthermore the book introduces representative large scale neuromorphic systems and reviews several recently implemented large scale digital neuromorphic systems by the authors providing corresponding application scenarios

*Proceedings of the Eighteenth Annual Conference of the Cognitive Science Society* Garrison W. Cottrell,2019-02-21 This volume features the complete text of all regular papers posters and summaries of symposia presented at the 18th annual meeting of the Cognitive Science Society Papers have been loosely grouped by topic and an author index is provided in the back In hopes of facilitating searches of this work an electronic index on the Internet s World Wide Web is provided Titles authors and summaries of all the papers published here have been placed in an online database which may be freely searched by anyone You can reach the Web site at <http://www.cse.ucsd.edu/events/cogsci96/proceedings> You may view the table of contents for this volume on the LEA Web site at <http://www.erlbaum.com> Pulsed Neural Networks Wolfgang

Maass,Christopher M. Bishop,2001-01-26 Most practical applications of artificial neural networks are based on a computational model involving the propagation of continuous variables from one processing unit to the next In recent years data from neurobiological experiments have made it increasingly clear that biological neural networks which communicate through pulses use the timing of the pulses to transmit information and perform computation This realization has stimulated significant research on pulsed neural networks including theoretical analyses and model development neurobiological modeling and hardware implementation This book presents the complete spectrum of current research in pulsed neural networks and includes the most important work from many of the key scientists in the field Terrence J Sejnowski s foreword *Neural Pulse Coding* presents an overview of the topic The first half of the book consists of longer tutorial articles spanning neurobiology theory algorithms and hardware The second half contains a larger number of shorter research chapters that present more advanced concepts The contributors use consistent notation and terminology throughout the book Contributors Peter S Burge Stephen R Deiss Rodney J Douglas John G Elias Wulfram Gerstner Alister Hamilton David Horn Axel Jahnke Richard Kempter Wolfgang Maass Alessandro Mortara Alan F Murray David P M Northmore Irit Opher Kostas A Papathanasiou Michael Recce Barry J P Rising Ulrich Roth Tim Sch nauer Terrence J Sejnowski John Shawe Taylor Max R van Daalen J Leo van Hemmen Philippe Venier Hermann Wagner Adrian M Whatley Anthony M Zador *Understanding and Bridging the Gap between Neuromorphic Computing and Machine Learning, volume II* Huajin Tang,Lei Deng ,Kaushik

Roy,2024-08-26 Towards the long standing dream of artificial intelligence two solution paths have been paved i neuroscience driven neuromorphic computing ii computer science driven machine learning The former targets at harnessing neuroscience to obtain insights for brain like processing by studying the detailed implementation of neural dynamics circuits coding and learning Although our understanding of how the brain works is still very limited this bio plausible way offers an appealing promise for future general intelligence In contrast the latter aims at solving practical tasks typically formulated as a cost function with high accuracy by eschewing most neuroscience details in favor of brute force optimization and feeding a large volume of data With the help of big data e g ImageNet high performance processors e g GPU TPU effective training algorithms e g artificial neural networks with gradient descent training and easy to use design tools e g Pytorch Tensorflow machine learning has achieved superior performance in a broad spectrum of scenarios Although acclaimed for the biological plausibility and the low power advantage benefit from the spike signals and event driven processing there are ongoing debates and skepticisms about neuromorphic computing since it usually performs worse than machine learning in practical tasks especially in terms of the accuracy

### **Innovations in Bio-Inspired Computing and Applications** Ajith

Abraham,Mrutyunjaya Panda,Subhrajit Pradhan,Laura Garcia-Hernandez,Kun Ma,2020-08-05 This book highlights recent research on bio inspired computing and its various innovative applications in information and communication technologies It presents 38 high quality papers from the 10th International Conference on Innovations in Bio Inspired Computing and Applications IBICA 2019 and 9th World Congress on Information and Communication Technologies WICT 2019 which was held at GIET University Gunupur India on December 16 18 2019 As a premier conference IBICA WICT brings together researchers engineers and practitioners whose work involves bio inspired computing computational intelligence and their applications in information security real world contexts etc Including contributions by authors from 18 countries the book offers a valuable reference guide for all researchers students and practitioners in the fields of Computer Science and Engineering

*Issues in Computation: 2011 Edition* ,2012-01-09 Issues in Computation 2011 Edition is a ScholarlyEditions eBook that delivers timely authoritative and comprehensive information about Computation The editors have built Issues in Computation 2011 Edition on the vast information databases of ScholarlyNews You can expect the information about Computation in this eBook to be deeper than what you can access anywhere else as well as consistently reliable authoritative informed and relevant The content of Issues in Computation 2011 Edition has been produced by the world s leading scientists engineers analysts research institutions and companies All of the content is from peer reviewed sources and all of it is written assembled and edited by the editors at ScholarlyEditions and available exclusively from us You now have a source you can cite with authority confidence and credibility More information is available at <http://www.ScholarlyEditions.com>

**Synaptic Plasticity for Neuromorphic Systems** Christian Mayr,Sadique Sheik,Chiara Bartolozzi,Elisabetta Chicca,2016-06-26 One of the most striking properties of biological systems is their ability to learn and adapt to ever

changing environmental conditions tasks and stimuli It emerges from a number of different forms of plasticity that change the properties of the computing substrate mainly acting on the modification of the strength of synaptic connections that gate the flow of information across neurons Plasticity is an essential ingredient for building artificial autonomous cognitive agents that can learn to reliably and meaningfully interact with the real world For this reason the neuromorphic community at large has put substantial effort in the design of different forms of plasticity and in putting them to practical use These plasticity forms comprise among others Short Term Depression and Facilitation Homeostasis Spike Frequency Adaptation and diverse forms of Hebbian learning e g Spike Timing Dependent Plasticity This special research topic collects the most advanced developments in the design of the diverse forms of plasticity from the single circuit to the system level as well as their exploitation in the implementation of cognitive systems      The MIT Encyclopedia of the Cognitive Sciences (MITECS) Robert A. Wilson, Frank C. Keil, 2001-09-04 Since the 1970s the cognitive sciences have offered multidisciplinary ways of understanding the mind and cognition The MIT Encyclopedia of the Cognitive Sciences MITECS is a landmark comprehensive reference work that represents the methodological and theoretical diversity of this changing field At the core of the encyclopedia are 471 concise entries from Acquisition and Adaptationism to Wundt and X bar Theory Each article written by a leading researcher in the field provides an accessible introduction to an important concept in the cognitive sciences as well as references or further readings Six extended essays which collectively serve as a roadmap to the articles provide overviews of each of six major areas of cognitive science Philosophy Psychology Neurosciences Computational Intelligence Linguistics and Language and Culture Cognition and Evolution For both students and researchers MITECS will be an indispensable guide to the current state of the cognitive sciences      Biologically Inspired Approaches to Advanced Information Technology Auke Jan Ijspeert, Masayuki Murata, Naoki Wakamiya, 2004-10-22 The evolution of the Internet has led us to the new era of the information infrastructure As the information systems operating on the Internet are getting larger and more complicated it is clear that the traditional approaches based on centralized mechanisms are no longer meaningful One typical example can be found in the recent growing interest in a P2P peer to peer computing paradigm It is quite different from the Web based client server systems which adopt essentially centralized management mechanisms The P2P computing environment has the potential to overcome bottlenecks in Web computing paradigm but it introduces another difficulty a scalability problem in terms of information found if we use a brute force flooding mechanism As such conventional information systems have been designed in a centralized fashion As the Internet is deployed on a world scale however the information systems have been growing and it becomes more and more difficult to ensure fault free operation This has long been a fundamental research topic in the field A complex information system is becoming more than we can manage For these reasons there has recently been a significant increase in interest in biologically inspired approaches to designing future information systems that can be managed efficiently and correctly



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