Analog Circuit Design
Analog Circuit Design

Robust Design, Sigma Delta Converters, RFID
Preface

This book is part of the Analog Circuit Design series and contains the revised contributions of all speakers of the 19th workshop on Advances in Analog Circuit Design (AADC), which was organized by Wolfgang Pribyl of Graz University of Technology. The workshop was held in the magnificent aula of the Graz University of Technology, Graz, Austria on March 23–25, 2010.

The book comprises 18 tutorial papers, divided in three chapters, each discussing a very relevant to-date topic in the area of analog circuit design. Each tutorial is presented by an expert in the field and state-of-the-art information is shared and discussed with the audience.

The topics of 2010 are:

1. Robust Design
2. Sigma Delta Converters
3. RFID

The aim of the AADC workshop is to bring together a group of expert designers to study and discuss new possibilities and future developments in the area of analog circuit design. Each AADC workshop has given rise to the publication of a book by Springer in their successful series of Analog Circuit Design. The series provides a valuable overview of analog circuit design and related CAD, mainly in the fields of basic analog modules, mixed-signal electronics, AD and DA converters, RF systems, robust and automotive electronics. It is a reference for whoever is engaged in these disciplines and wishes to keep abreast of the latest developments in the field. The full list of the previous books and topics in the series is enclosed below.

We sincerely hope that this 19th book continues the tradition and provides a valuable contribution to our Analog Design Community.

Herman Casier
### Table

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Topics</th>
</tr>
</thead>
</table>
| 2009 | Lund (Sweden) | Smart Data Converters  
Filters on Chip  
Multimode Transmitters |
| 2008 | Pavia (Italy) | High-speed Clock and Data Recovery  
High-performance Amplifiers  
Power Management |
| 2007 | Oostende (Belgium) | Sensors, Actuators and Power Drivers for the Automotive  
and Industrial Environment  
Integrated PA’s: from Wireline to RF  
Very High Frequency Front Ends |
| 2006 | Maastricht (The Netherlands) | High-Speed AD Converters  
Automatic Electronics: EMC issues  
Ultra Low Power Wireless |
| 2005 | Limerick (Ireland) | RF Circuits: Wide Band, Front-Ends, DAC’s  
Design Methodology and Verification of RF and Mixed-Signal Systems  
Low Power and Low Voltage |
| 2004 | Montreux (Switzerland) | Sensor and Actuator Interface Electronics  
Integrated High-Voltage Electronics and Power Management  
Low-Power and High-Resolution ADCs |
| 2003 | Graz (Austria) | Fractional-N Synthesizers  
Design for Robustness  
Line and Bus drivers |
| 2002 | Spa (Belgium) | Structured Mixed-Mode Design  
Multi-Bit Sigma-Delta Converters  
Short-Range RF Circuits |
| 2001 | Noordwijk (The Netherlands) | Scalable Analog Circuit Design  
High-Speed D/A Converters  
RF Power Amplifiers |
| 2000 | Munich (Germany) | High-Speed A/D Converters  
Mixed-Signal Design  
PLLs and Synthesizers |
| 1999 | Nice (France) | (X)DSL and other Communication Systems  
RF-MOST Models and Behavioural Modeling  
Integrated Filters and Oscillators |
| 1998 | Copenhagen (Denmark) | 1-Volt Electronics  
Mixed-Mode Systems  
LNA’s and RF Power Amplifiers for Communications |
| 1997 | Como (Italy) | RF Analog to Digital Converters  
Sensor and Actuator Interfaces  
Low-Noise Oscillators, PLLs and Synthesizers |
| 1996 | Lausanne (Switzerland) | RF CMOS Circuit Design  
Bandpass Delta-Sigma and Other Data Converters  
Translinear Circuits |
| 1995 | Villach (Austria) | Low-Noise, Low-Power, Low-Voltage  
Mixed-Mode design with CAD tools  
Voltage, Current and Time References |
| 1994 | Eindhoven (The Netherlands) | Low-Power Low-Voltage  
Integrated Filters  
Smart Power |
<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>Leuven (Belgium)</td>
<td>Mixed Analogue-Digital Circuit Design</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensor Interface Circuits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Communication Circuits</td>
</tr>
<tr>
<td>1992</td>
<td>Scheveningen (Netherlands)</td>
<td>Operational Amplifiers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analog to Digital Conversion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analog Computer Aided Design</td>
</tr>
</tbody>
</table>
## Contents

Part I Robust Design ............................................................... 1

Modeling and Design for Reliability of Analog Integrated Circuits in Nanometer CMOS Technologies ........................................ 3
    Georges Gielen, Elie Maricau and Pieter De Wit

Modeling and Simulation of Statistical Variability in Nanometer CMOS Technologies .......................................................... 17
    A. Asenov and B. Cheng

Advanced Physical Design in Nanoscale Analog CMOS ...................... 35
    Lanny L. Lewyn

Robust Design for High Temperature and High Voltage Applications ...... 53
    Ovidiu Vermesan, Edgard Laes, Marco Ottella, Mamun Jamal, Jan Kubik, Kafil M. Razeeb, Reiner John, Harald Gall, Massimo Abrate, Nicolas Cordero and Jan Vcelak

Radiation Effects and Hardening by Design in CMOS Technologies .......... 69
    Federico Faccio

EMC Robust Design for Smart Power High Side Switches ..................... 89
    Paolo Del Croce and Bernd Deutschmann

Part II Sigma Delta Converters ............................................... 105

Noise-Coupled Delta-Sigma ADCS ............................................ 107
    Kyehyoung Lee and Gabor C. Temes

Very Low OSR Sigma-Delta Converters ....................................... 135
    Trevor C. Caldwell
## Comparator-Based Switched-Capacitor Delta-Sigma A/D Converters

Koen Cornelissens and Michiel Steyaert

157

## VCO-Based Wideband Continuous-Time Sigma-Delta Analog-to-Digital Converters

Michael H. Perrott

177

## Wideband Continuous-Time Multi-Bit Delta-Sigma ADCs

J. Silva-Martinez, C.-Y. Lu, M. Onabajo, F. Silva-Rivas, V. Dhanasekaran and M. Gambhir

203

## Oversampled DACs

Andrea Baschirotto, Vittorio Colonna and Gabriele Gandolfi

227

## Part III RFID

Henri Barthel

257

## RFID, a Technology Ready for Industry Deployment

Mitsuo Usami

259

## The World’s Smallest RFID Chip Technology

Raymond Barnett

277

## RF and Low Power Analog Design for RFID

Albert Missoni, Günter Hofer and Wolfgang Pribyl

289

## Printed Electronics—First Circuits, Products, and Roadmap

Jürgen Krumm and Wolfgang Clemens

333

## Towards EPC-Compatible Organic RFID Tags

Kris Myny, Soeren Steudel, Peter Vicca, Steve Smout, Monique J. Beenhakers, Nick A. J. M. van Aerle, François Furthner, Bas van der Putten, Ashutosh K. Tripathi, Gerwin H. Gelinck, Jan Genoe, Wim Dehaene and Paul Heremans

347
Contributors

Massimo Abrate  Centro Ricerche FIAT S.C.p.A., Strada Torino 50, 10043 Orbassano, Torino, Italy

Nick A. J. M. van Aerle  Polymer Vision, Eindhoven, The Netherlands  
ASML, Veldhoven, The Netherlands

A. Asenov  Department of Electronics and Electrical Engineering, 
The University of Glasgow, Glasgow G12 0LT, UK

Raymond Barnett  Texas Instruments, Texas, USA

Henri Barthel  GS1 Global Office, Brussels, Belgium

Andrea Baschirotto  Department of Physics “G. Occhialini”, 
University of Milano Bicocca, Milano, Italy  
e-mail: andrea.baschirotto@unimib.it

Monique J. Beenakkers  Polymer Vision, Eindhoven, The Netherlands

Trevor C. Caldwell  Analog Devices, University of Toronto, Toronto, Canada

B. Cheng  Department of Electronics and Electrical Engineering, 
The University of Glasgow, Glasgow G12 0LT, UK

Wolfgang Clemens  PolyIC GmbH & Co.KG, Tucherstraße 2, 90763 Fürth, Germany

Vittorio Colonna  Marvell, Pavia, Italy  
e-mail: vcolonna@marvell.com

Nicolas Cordero  Tyndall National Institute, Lee Maltings, Prospect Row,  
Cork, Ireland

Koen Cornelissen  ESAT-MICAS, K.U. Leuven, Kasteelpark Arenberg 10, 3001 Leuven, Belgium
Contributors

Paolo Del Croce  Infineon Technologies AG, Siemensstrasse 2, 9500 Villach, Austria
e-mail: paolo.delcroce@infineon.com

Wim Dehaene  IMEC, Leuven, Belgium;
Katholieke Universiteit Leuven, Leuven, Belgium

Bernd Deutschmann  Infineon Technologies AG, Am Campeon 1–12, 85579 Neubiberg, Germany
e-mail: bernd.deutschmann@infineon.com

V. Dhanasekaran  Electrical and Computer Engineering, Analog and Mixed-Signal Center, Texas A&M University, College Station, TX, USA

Federico Faccio  PH dept., CERN, 1211 Geneva 23, Switzerland

François Furthner  TNO Science and Industry, Eindhoven, The Netherlands

Harald Gall  austriamicrosystems AG, Tobelbaderstrasse 30, 8141 Unterpremstaetten, Austria

M. Gambhir  Electrical and Computer Engineering, Analog and Mixed-Signal Center, Texas A&M University, College Station, TX, USA

Gabriele Gandolfi  Marvell, Pavia, Italy
e-mail: gabriele@marvell.com

Gerwin H. Gelinck  TNO Science and Industry, Eindhoven, The Netherlands

Jan Genoe  IMEC, Leuven, Belgium;
Katholieke Hogeschool Limburg, Diepenbeek, Belgium

Georges Gielen  ESAT-MICAS, Katholieke Universiteit Leuven, Leuven, Belgium
e-mail: gielen@esat.kuleuven.be

Paul Heremans  IMEC, Leuven, Belgium
Katholieke Universiteit Leuven, Leuven, Belgium

Günter Hofer  Infineon Technologies Austria AG, Graz, Austria

Mamun Jamal  Tyndall National Institute, Lee Maltings, Prospect Row, Cork, Ireland

Reiner John  Infineon Technologies AG, Am Campeon 1-12, 85579 Neubiberg, Germany

Jürgen Krumm  PolyIC GmbH & Co.KG, Tucherstraße 2, 90763 Fürth, Germany

Jan Kubik  Tyndall National Institute, Lee Maltings, Prospect Row, Cork, Ireland

Edgard Laes  ON Semiconductor Belgium BVBA, Senneberg, J. Monnetlaan, 1804 Vilvoorde, Belgium
Contributors

Kyehyung Lee  Conexant Systems, Newport Beach, CA 92660, USA

Lanny L. Lewyn  Lewyn Consulting Inc., Laguna Beach, CA, USA
e-mail: lanny@pacbell.net

C.-Y. Lu  Electrical and Computer Engineering, Analog and Mixed-Signal Center,
Texas A&M University, College Station, TX, USA

Elie Maricau  ESAT-MICAS, Katholieke Universiteit Leuven, Leuven, Belgium

Albert Missoni  Infineon Technologies Austria AG, Graz, Austria;
Graz University of Technology Institute of Electronics, Graz, Austria

Kris Myny  IMEC, Leuven, Belgium;
Katholieke Hogeschool Limburg, Diepenbeek, Belgium;
Katholieke Universiteit Leuven, Leuven, Belgium

Marco Ottella  Centro Ricerche FIAT S.C.p.A., Strada Torino 50,
10043 Orbassano, Torino, Italy

M. Onabajo  Electrical and Computer Engineering, Analog and Mixed-Signal
Center, Texas A&M University, College Station, TX, USA

Michael H. Perrott  SiTime Corporation, Sunnyvale, USA
e-mail: mhperrott@gmail.com

Wolfgang Pribyl  Graz University of Technology Institute of Electronics,
Graz, Austria

Bas van der Putten  TNO Science and Industry, Eindhoven, The Netherlands

J. Silva-Martinez  Electrical and Computer Engineering, Analog and Mixed-
Signal Center, Texas A&M University, College Station, TX, USA

Kafil M. Razeeb  Tyndall National Institute, Lee Maltings, Prospect Row, Cork,
Ireland

F. Silva-Rivas  Electrical and Computer Engineering, Analog and Mixed-Signal
Center, Texas A&M University, College Station, TX, USA

Steve Smout  IMEC, Leuven, Belgium

Soeren Steudel  IMEC, Leuven, Belgium

Michiel Steyaert  Dept. Elektrotechniek, ESAT-MICAS, K.U. Leuven, Kardinaal
Mercierlaan 94, B-3001 Heverlee, Belgium
e-mail: michiel.steyaert@esat.kuleuven.ac.be

Gabor C. Temes  Oregon State University, Corvallis, OR 97331, USA

Ashutosh K. Tripathi  TNO Science and Industry, Eindhoven, The Netherlands

Mitsuo Usami  Central Research Laboratory, Hitachi Ltd., 1-280 Higashi-
Koigakubo, Kokubunji-shi, 185-8601 Tokyo, Japan
e-mail: mitsuo.usami.fc@hitachi.com
Jan Vcelak  Tyndall National Institute, Lee Maltings, Prospect Row, Cork, Ireland

Ovidiu Vermesan  SINTEF, Forskningsvn. 1, P.O.Box 124 Blindern, 0314 Oslo, Norway

Peter Vicca  IMEC, Leuven, Belgium

Pieter De Wit  ESAT-MICAS, Katholieke Universiteit Leuven, Leuven, Belgium