FINAL Report on IEEE CASS Outreach Initiative 2015, ID=1015

Event Title: Inter- and Cross-disciplinary Topics in Circuits and Systems Community.

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Brief description of the activity: it consisted in two workshops and a ten-day Ph.D. course that were held at Politecnico di Milano or in the facilities of research centers during the period June-October 2015, as follows:

- June 8, 2015: Workshop on Advanced Topics In Microelectronic Engineering (ATIME 2015/01)
- From June 24 to July 3, 2015: ten-day PhD class course "Introduction to Compact Dynamical Modeling".
- October 29, 2015: Seminar on Emerging Topics in IEEE Circuits and Systems Community

The subjects of the presentations have been selected among the relevant topics covered by the research journals of the Society. The activities have brought together researchers working in academia, in industry, as well as master and PhD students. On the whole, more than 100 persons attended the events. These include people with Politecnico di Milano, Politecnico di Torino, University College Cork, University of Limerick, Massachusetts Institute of Technology, Tyndall National Institute (Cork), Analog Devices (Limerick), Xilinx (Limerick), STMicroelectronics (Agrate Brianza), Centro Nazionale Ricerche (CNR). The slides of the presentations have been collected and are available, upon request, to CASS members. The activity have been announced on the CASS web site and on the web page of the Politecnico di Milano, DEIB. The flyers of the events and the final report mini-articles are described in the next pages.

How the budget was expended.

The budget has been used to cover travel, accommodation and meal expenses for the speakers and teachers and for organization expenses, as follows:

- Workshop June 8: 2,400 USD
- Ten-day PhD course 5,200 USD
- Workshop October 29: 400 USD
- VAT for fund transfer from IEEE Italy Section 1,800 USD
- Department fees/costs: 600 USD
- Total: 10,400 USD
Advanced Topics In Microelectronic Engineering
ATIME 2015/01

Workshop on
“Advances in Frequency Synthesis”

Salvatore LEVANTINO and Paolo MAFFEZZONI
Politecnico di Milano, Italy

Sponsored by the IEEE Circuits and Systems Society
Activity: “Inter- and Cross-disciplinary Topics in Circuits
and Systems Community”

Monday, 08 June 2015

Auditorium
Analog Devices
Raheen Industrial Estate, Limerick, Ireland

09:00–09:30 Registration
09:30–11:00 Advanced Digital Phase-Locked Loops (Part 1)
11:00–11:30 Break
11:30–13:00 Advanced Digital Phase-Locked Loops (Part 2)
13:00–14:00 Lunch
14:00–15:30 Phase-domain modeling of oscillators: theory and applications

Space is limited so admission is by pre-registration only

If you wish to attend, please email peter.kennedy@ucc.ie
before 18 May 2015 with the subject “ATIME 2015/01”
Advanced Digital Phase-Locked Loops
Salvatore Levantino
Politecnico di Milano

Abstract:

After reviewing the tradeoffs of conventional analog loops, this tutorial will introduce the fundamentals of digital phase-locked loops and analyze the mechanisms of generation of limit cycles, which manifest themselves as spurious tones at the output. Then, we will compare two different quantization strategies and develop practical design examples showing how to set loop parameters and optimize phase noise and jitter. The second part of the tutorial will be devoted to fractional-\(N\) synthesis, in which quantization and nonlinearity add new sources of spurious tones: We will review the different design techniques which help mitigate such impairments. Finally, examples of state-of-the-art implementations of frequency synthesizers and direct-FM modulators based on digital PLLs will be discussed.

Salvatore Levantino is Associate Professor of Electrical Engineering at Politecnico di Milano, Milan, Italy. His research includes wireless transceivers, frequency synthesizers, and data converters. Author of more than 80 papers on IEEE journals and conferences and the book "Integrated Frequency Synthesizers for Wireless Systems" published by CUP in 2007. He is associate Editor of IEEE TCAS-I and member of the Steering Committee for the IEEE RFIC Symposium.

Phase-domain modeling of oscillators: theory and applications
Paolo Maffezzoni
Politecnico di Milano

Abstract:

Due to circuit complexity, the analysis and design of Analog and Mixed-signal electronics should rely on compact modeling of the functional blocks composing the system and consequent high-level behavioral simulation. In this context, compact macro-modeling of oscillators plays a crucial role. Oscillator macro-models are in fact central to efficiently evaluating the phase-noise performance of PLLs or to investigating synchronization effects in oscillator arrays. In the first part of this talk, we will review the fundamentals of oscillators phase-domain macro-modeling. We will underline how such a technique consists of computing a scalar periodic function that measures the oscillator phase-sensitivity to a given perturbation. Several methods to extract the phase-sensitivity response (PSR) will be presented. In the second part of the talk we will illustrate three applications: a) the analysis of phase-noise mechanism in unconventional oscillator topologies, b) the behavioral phase-noise simulation of digital PLLs and c) the design of multi-phase oscillators.

Paolo Maffezzoni is currently an Associate Professor of electrical engineering at Politecnico di Milano, Italy, where since 2004 he teaches basic Circuit Theory. His research interests include advanced computational methods for the simulation, design and verification of nonlinear circuits and systems, analysis of phase noise and synchronization effects in oscillators, behavioral simulation of analog and mixed-signals systems. On these issues, he has published 62 papers in ISI Journals and 59 papers in peer-referred conferences. Currently, he is serving as an Associate Editor for the IEEE Transactions on Computer-Aided-Design of Integrated Circuits and Systems (TCAD) and as a member of the Technical Program Committee of the ACM/IEEE Design Automation Conference (DAC).
The workshop has been sponsored in part by the IEEE CASS Outreach Activity Inter- and Cross-disciplinary Top- ics in Circuits and Systems Community. It consisted in a full-day meeting between students and researchers working in academia and research centers (University College Cork, Tyndall National Institute, Politecnico di Milano), as well as researchers working in industry (e.g. Analog Devices Inc, Xilinx). The meeting was held in the facilities of Analog Devices, in Limerick, Ireland and was free of charge and open to anyone interested under registration. The event was attended in person by more than 50 people plus about 20 people connected online. The meeting was opened by Prof. Michael Peter Kennedy, University College Cork, who introduced the speakers. The morning was completely devoted to the presentation “Advanced Digital Phase-Locked Loops” given by Prof. Salvatore Levantino, Politecnico di Milano. After reviewing the tradeoffs of conventional analog loops, the lecture introduced the fundamentals of digital phase-locked loops and analyzed the mechanisms of generation of limit cycles, which manifest themselves as spurious tones at the output. Different quantization strategies were compared and practical design examples were given showing how to set loop parameters and optimize phase noise and jitter. The second part of the tutorial was devoted to fractional-N synthesis, in which quantization and nonlinearity add new sources of spuri- ous tones. Different design techniques were illustrated which help mitigate such impairments. Finally, examples of state-of-the-art implementations of frequency synthesizers and direct- FM modulators based on digital PLLs were discussed. In the afternoon, Prof. Paolo Maffezzoni, Politecnico di Milano gave the talk “Phase-domain modeling of oscillators: theory and applications”. In this second presentation, the fundamentals of oscillators phase-domain modeling were reviewed. Then, two applications were illustrated: (i) analysis of phase-noise mechanism in unconventional oscillator topologies, (ii) behavioral phase-noise simulation of digital PLLs. The meeting was concluded with open discussion and questions. It emerged how Analog and Mixed-signal electronics is rapidly evolving due to technological trends (e.g. extremely high frequency applications, limited power budget). It was underlined the importance of the interdisciplinary roles of applied and basic research as well as the interplay between academia and industry. During the event, the support given by IEEE CASS was acknowledged and details on how to join the CASS clearly provided to the attendees.
PhD class course “Introduction to compact dynamical modelling”

Prof. Luca Daniel
Massachusetts Institute of Technology (MIT)

Sponsored by the IEEE Circuits and Systems Society
Activity: “Inter- and Cross-disciplinary Topics in Circuits and Systems Community”

From June 24 2015 to July 3 2015

Dipartimento di Elettronica, Informazione e Bioingegneria
Politecnico di Milano, Via Ponzio 34/5, Milan, Italy

Time Schedule:

June 24: 10-12.30; 14.30-17;
June 25: 10-12.30; 14.30-17;
June 26: 10-12;
June 29: 15-17;
June 30: 14-17;
July 1: 10-12.30; 14.30-17;
July 2: 10-12.30; 14.30-17;
July 3: 10-12

Latest updates at: home.deib.polimi.it/pmaffezz/event.html

This course is inserted into the Programme of the PhD School of Politecnico di Milano. Participation of non PhD students is admitted free of charge by mailing to pmaffezz@elet.polimi.it
Course description

Many complex systems developed by engineers (e.g. labs on chips, iPads, magnetic resonance imaging scanners, nationwide electrical/gas/oil transportation network, or buildings/automotive/aircraft frames) or found in nature (e.g. the human cardiovascular system, the brain neural network, biological systems, or the geophysical network of oil/water/gas reservoirs) can be viewed as large collections of interconnected dynamical system components. The performance and characteristics of each individual component critically depend on what engineers or scientists refer to as “second order effects”, and can be captured only by resorting to expensive partial differential equation solvers. In addition, components are often affected by random uncertainties in parameters and in geometries.

In this course we will survey several techniques for modeling and simulation and uncertainty quantification of a large variety (e.g. aerospace, mechanical, electrical, energy and biomedical) of engineering and physical complex systems. Detailed examples will be presented, drawn from a variety of engineering disciplines e.g. Electrical Engineering (interconnect networks including parasitics; fullwave electromagnetic structures; analog and digital circuits including nonlinear semiconductor devices and Micro-Electro-Mechanical Devices), Mechanical Engineering (frame modeling, heat diffusion, fluid-dynamics and oil transport), Civil Engineering (structural problems, vibrations), Material Sciences (inverse problems for identification of material properties), Biomedical Engineering (biochemical reactions and the human cardio-vascular system).

Target goal: Provide students access to the state of the art in numerical tools in order to help them with their research projects involving analysis, design and optimization problems in a variety of different engineering and science disciplines dealing with complex systems.

The focus of the course will not be on mathematical formalism and rigorous theorem proving, but rather on developing general intuition and practical implementation skills.

Class project and evaluation: students will be working on a project involving modeling and simulation of a complex system either assigned, or chosen from their own field of research.

Final evaluations will be based on interaction with the staff during the course and a final report.

Short CV

Luca Daniel received the Ph.D. degree in Electrical Engineering from the University of California, Berkeley, in 2003. He is currently a Full Professor in the Electrical Engineering and Computer Science Department of the Massachusetts Institute of Technology (MIT). Industry experiences include HP Research Labs, Palo Alto (1998) and Cadence Berkeley Labs (2001). His current research interests include integral equation solvers, uncertainty quantification and parameterized model order reduction, applied to RF circuits, silicon photonics, MEMs, Magnetic Resonance Imaging scanners, and the human cardiovascular system. Prof. Daniel was the recipient of the 1999 IEEE Trans. on Power Electronics best paper award; the 2003 best PhD thesis awards from the Electrical Engineering and the Applied Math departments at UC Berkeley; the 2003 ACM Outstanding Ph.D. Dissertation Award in Electronic Design Automation; the 2009 IBM Corporation Faculty Award; the 2010 IEEE Early Career Award in Electronic Design Automation; the 2014 IEEE Trans. On Computer Aided Design best paper award; and seven best paper awards in conferences.
The course has been sponsored in part by the IEEE CASS Outreach Activity Inter- and Cross-disciplinary Topics in Circuits and Systems Community. The event consisted in a ten-day class given by Prof. Luca Daniel, Massachusetts Institute of Technology (MIT), to the students of the Ph.D. School of the Politecnico di Milano. The School covers several education disciplines (among which electrical, computer science, civil, mechanical, energy, aerospace and biomedical). Some methodologies that are consolidated in the CAS community, e.g. circuit paradigm, system dynamics, complexity reduction, can be shared by other engineering communities in a cross-disciplinary way. In fact, many complex systems developed by engineers (e.g. labs on chips, iPads, magnetic resonance imaging scanners, nationwide electrical/gas/oil transportation network, or buildings/automotive/aircraft frames) or found in nature (e.g. the human cardiovascular system, the brain neural network, biological systems, or the geophysical network of oil/water/gas reservoirs) can be viewed as large collections of interconnected dynamical system components. The performance and characteristics of each individual component critically depend on what engineers or scientists refer to as second order effects, and can be captured only by resorting to expensive partial differential equation solvers. The course provided a survey of several techniques for modeling and simulation of a large variety (e.g. aerospace, mechanical, electrical, energy and biomedical) of engineering and physical complex systems. Fig. 1 shows Prof. Daniel while illustrating the idea of “Moment Matching” which is a key step in model order reduction. The course was attended by Ph.D. students of Politecnico di Milano who, after final evaluation, will receive educational credits valid for their Ph.D. track. The class was also attended by some students coming from the nearby university of Politecnico di Torino. On the whole more than 20 people participated to the event. The activity was composed of lesson hours given by Prof. Daniel as well as by in-class student work. During in-class activity students worked, individually or in team, on an implementation project involving modeling and simulation of a complex system either assigned, or chosen from their own field of research. Final evaluations is based on a final presentation or report. Three teams succeeded in concluding their project by July 3 and to present their results to the staff and to other students, Figs. 2, 3, 4.

Other teams will present their project for evaluation by the fall 2015. During the event, the support given by IEEE CASS was acknowledged and details on how to join the CASS clearly provided to the attendees. Students were also encouraged to write a paper to submit to one of the Journals or to a sister Conference sponsored by CASS.
Seminar:
“Emerging Topics in IEEE Circuits and Systems”

Sponsored by the IEEE CASS outreach activity:
“Inter- and Cross-disciplinary Topics in Circuits and Systems Community”

Thursday, 29 October 2015

Aula Beta, Building 24
Politecnico di Milano, DEIB
Via Golgi 40, Milan, Italy

14:30–14:40 Opening: the IEEE CASS vision
15:20–15:50 Phase and amplitude noise in oscillators, and potential application to energy harvesting
16:00–16:30 Thin-film Piezo for next wave of MEMS actuators
16:40–17:00 Discussion

Participation is free of charge
Inertial Energy Harvesting in MEMS: Some Recent Trends
Raffaele Ardito
Politecnico di Milano

Abstract: The application of piezoelectric materials is continuously increasing, with different possible uses of both “direct” (conversion of mechanical into electric energy) and “indirect” effect. The latter is applied for actuating purposes, e.g. in the case of micropumps; “direct” effect is now widely used for energy harvesting. In recent times, the concept of energy harvesting has been applied to MEMS devices, with similar functioning principles: an additional broadening of applications can be forecast in the future, with the immediate corollary of a fundamental need for improved computational tools. The talk will be focused on the fundamentals of inertial energy harvesting, for possible application at the MEMS scale. After a short presentation of the state-of-the-art, some details will be provided on computational techniques, which can be used to predict the actual behavior of MEMS device and to carry out the optimization process on the basis of Design of Experiments (DOE) procedures. Finally, some specific provisions for improving the harvester performances will be discussed.

Raffaele Ardito is associate professor of Structural Mechanics at the Politecnico di Milano. He graduated in 2000 (cum laude) at the Politecnico di Milano in Civil Engineering. Between 2001 and 2004 he has been Ph.D. student in Structural Engineering (Politecnico di Milano); he received the Ph.D. degree, cum laude, in 2004. Since 2004 to 2006 he has been research fellow at the National Institute for Nuclear Physics, joining an international research group with focus on solid mechanics in cryogenic conditions. In 2007, he was back in the Politecnico di Milano and he started working on the topic of multi-physics simulations for Micro-Electro-Mechanical Systems (MEMS). He spent, in 2008 and 2010, two periods of research at the Research Laboratory of Electronics, Massachusetts Institute of Technology, as visiting scientist. He is co-inventor of two patents and co-author of more than 80 publications on structural mechanics and numerical methods; among them, 30 publications are papers on International Journals. In 2000, he got the Maddalena prize for the best Master Thesis in Civil Engineering and Architecture. In 2009 he has been awarded the "Young researcher" grant from the Dept. of Structural Engineering, Politecnico di Milano. His scientific interests are theoretical and computational aspects of multi-physics behavior of MEMS.

Phase and amplitude noise in oscillators, and potential application to energy harvesting
Michele Bonnin
Politecnico di Torino

Abstract: Energy harvesting promises to be a disruptive technology, making self-powered devices available for a large number of applications. Many of the devices proposed for energy harvesting are based on oscillators that collect the energy from random vibrations. It has been shown that in certain situation nonlinear oscillators may outperform their linear counterparts. In this talk we present a mathematical framework to study the dynamical behavior of nonlinear oscillators subject to perturbations modelled by white Gaussian noise. The method is based on the idea to describe the oscillator’s dynamics in terms of amplitude and phase variables, that are the ideal framework for evaluating energy harvesting performances. Making use of the theory of stochastic differential equations and Itô calculus, a rigorous set of equations for the phase and the amplitude of oscillators of any order is derived. It will be shown that the noise influences not only the amplitude of the oscillations, but also the expected frequency. Using Floquet theory, it will be shown that a partial decoupling between the phase and the amplitude dynamics can be obtained, and how reduced order models can be derived. Potential applications to energy harvesting and stochastic resonance will be discussed.

Michele Bonnin received the Laurea degree in Physics from the University of Turin, Italy, and the Ph.D. degree in Electronic and Communication Engineering from the Politecnico di Torino, Italy, in 2003 and 2007, respectively. From 2007 to 2011 he was research associate with the Department of Electronics of Politecnico di Torino. In 2011 he joined the Department of Electronics and Telecommunications of Politecnico di Torino as Assistant Professor. His research interests include the theory of dynamical systems, both quantum and classical, and its application to circuits and systems. He is author or coauthor of more than 60 papers published on international journals and international conference proceedings. Michele Bonnin was the recipient of the 2004 Best Paper of the Year Award by the International Journal of Circuit Theory and Applications. He was the conference secretary for the 3th International Workshop on Cellular Nanoscale Networks and their Applications and for the 3rd Symposium on Memristor.
Thin-film Piezo for next wave of MEMS actuators
Dino Faralli
STMicroelectronics

Abstract: A growing number of applications is pushing the development of smart-systems which integrates MEMS sensors and actuators, with an increased demand of new ways to interface the system versus man and ambient. New enabling technologies are required to be available in manufacturing lines to allow for prototyping and production of such devices. A pilot line for integration of piezoelectric thin-films into MEMS devices has been recently installed in the STMicroelectronics Fab in Agrate Brianza. A summary of the technology module and characterization of the piezo materials will be shown, together with an overview of the products under development.

Dino Faralli received the Laurea degree in Physics in 1996 and PhD degree in Theoretical Physics in 2000 from the University of Perugia, Italy. He is currently working as MEMS technology development team leader, responsible for development of MEMS technologies and products, with focus on piezo-electric materials, within the AMS group of STMicroelectronics, based in Agrate Brianza, Italy. He has 15 years experience in technology development from the concept phase, to industrialization and manufacturing. He worked on development of several technologies which reached product maturity and manufacturing phase e.g. High Voltage and Smart Power BCD, BCD 200V on SOI, Pressure sensors, Accelerometers, Probe storage devices, Thermal and Piezoelectric Inkjet print-heads. He holds 16 patent applications and scientific publications in the semiconductor technology field.
Seminar “Emerging Topics in IEEE Circuits and Systems”
Politecnico di Milano
October 29, 2015

The seminar has been sponsored by the IEEE CASS Outreach Activity Inter- and Cross-disciplinary Topics in Circuits and Systems Community. The purpose of the seminar was that of bringing together researchers and students from different areas of engineering or different research centers and universities interested to the topic of energy harvesting and technology for energy harvesting. The seminar consisted in three presentations and a final collective discussion.

The first presentation was held by Prof. Raffaele Ardito, Politecnico di Milano, who underlined how, in recent times, the concept of energy harvesting has been applied to MEMS devices fabricated in piezoelectric materials. The talk was focused on the fundamentals of inertial energy harvesting, for possible application at the MEMS scale. After a short presentation of the state-of-the-art, some details were provided on computational techniques, which can be used to predict the actual behavior of MEMS device and to carry out the optimization process on the basis of Design of Experiments (DOE) procedures.

The second presentation was done by Prof. Michele Bonnin, Politecnico di Torino. Prof. Bonnin highlighted that many of the devices proposed for energy harvesting are based on oscillators that collect energy from random vibrations. In certain situations, nonlinear oscillators may outperform their linear counterparts. The talk presented a mathematical framework to study the dynamical behavior of nonlinear oscillators subject to perturbations modelled by white Gaussian noise. The presented method is based on the idea to describe the oscillators dynamics in terms of amplitude and phase variables, that are the ideal framework for evaluating energy harvesting performances. Potential applications to energy harvesting and stochastic resonance were then discussed.

The final presentation was given by Dr. Dino Faralli, STMicroelectronics, who focused on technological issues connected to the development of smart-systems which integrates MEMS sensors and actuators. Dr. Faralli presented a new pilot line for integration of piezoelectric thin-films into MEMS devices recently installed in the facilities of STM in Agrate Brianza. A summary of the technology module and characterization of the piezo materials were surveyed together with an overview of the products under development. The seminar was attended by more than 15 people that involve students of Politecnico di Milano and Torino, researchers of STMicroelectronics and of Centro Nazionale delle Ricerche (CNR). At the opening of the event, the support given by IEEE CASS was acknowledged and details on how to join the CASS clearly provided to the attendees. It was underlined how the topic of energy harvesting requires a multi-disciplinary and multi-physics approach just in the spirit of CASS vision.