From the Guest Editors

Tokunbo Ogunfunmi
Ravi P. Ramachandran
Joos Vandewalle



The pace of technological innovation is mind-boggling. Technologies that did not exist just a few years ago are now commonplace and being used to underlie world economies. A few examples include the influence of internet/information technology and nano-technologies in banking, social networking, engineering, law enforcement and medicine.

Electrical engineers have been largely responsible for the development of these new technologies. The fundamental theories of electrical engineering have not changed much over the years (since their invention in the last century). However, the systems of educational delivery and learning opportunities need to now be updated by these same technological advances. For example, online education over the internet, Massively Open Online Courses (MOOCs), Google search for information worldwide, etc., have impacted the way we learn.

In addition, new linkages have been discovered to connect various knowledge areas in electrical engineering. Therefore, it is important to explore connections between the traditional areas of electrical engineering especially in the Circuits and Systems (CAS) areas.

Education of the next generation of engineers should keep pace with the rate of technological innovation. There is an urgent need to *re-think* the way we educate our students to take advantage of these linkages, use new technologies of educational delivery and adapt our curricula to better deliver the educational experience and mastery necessary to produce top engineers.

It is necessary for *all* engineers especially at the undergraduate level to understand many of the innovations in electrical engineering that are so pervasive today. As such, all engineering majors require at least a first course in Electric Circuits in their core curriculum. In addition, Electric Circuits course is a core component of undergraduate curricula in Electrical, Electronic and Computer Engineering programs worldwide. Other courses include Linear Systems, Digital Signal Processing, Logic Design, Analog Electronics, Digital Electronics, Power Electronics, etc. which build on the foundation of this core course.

The Circuits and Systems (CAS) Society established a new Technical Committee in 2009. This was pursuant to a major gathering (workshop) organized by Dr. Joos Vandewalle at the 2008 ISCAS conference in Seattle. From 2008 came the impetus to form the IEEE CAS Society Technical Committee on Educational Outreach (CASEO TC) which was later established.

A special issue of the *CAS Magazine* was published containing some papers from this workshop. Dr. Joos Vandewalle became the founding chair of the CASEO TC and has been very instrumental in its growth. The TC has been very active, recruited several members, organized ISCAS annual regular and special sessions and contributed to the growth of the CAS Society. Today, the CASEO TC membership has grown to about 50 (see our CASEO TC website http://ieee-cas.org/community/technical-committees/caseo-tc). It has been five years since this major gathering and the creation of the CASEO TC.

The Circuits and Systems Education and Outreach Technical Committee (CASEO TC) focuses on the education and outreach of circuits and systems. The TC addresses the role, the process and the promotion of the education of CAS subjects in electrical engineering education and makes initiatives to enhance its quality and attraction worldwide. Special attention is devoted to outreach initiatives that stimulate youngsters to CAS items worldwide, and to the social and ethical role of CAS related topics.

As part of the activities of this CASEO TC, we have focused for several years on various ways to improve how we deliver education at the undergraduate and graduate levels. An example is the development and use of Concept Inventories for Circuits and Systems Courses.

In 2013, after the IEEE ISCAS conference in Beijing, China, the CASEO TC organized a one-day workshop entitled: *Re-Thinking Circuits and Systems Education: Exploring New Pedagogies and Approaches*. The workshop had several invited speakers and attracted more than thirty attendees.

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It is fair to say that CAS education is now at a crossroad. Grand challenges are driving innovation. Challenges such as Energy and Sustainability are issues for which engineers have to provide solutions. Alternate pedagogies (e.g. the Conceiving Defining Implementing Operating (CDIO) concept for real world systems and products (see http://www.cdio.org/)) are being introduced. The role of the internet is expanding how education is delivered. Tools such as Wikipedia, online learning, etc. are pervasive now. There is still a debate about whether we teach analog or digital as a first course in CAS. Methods such as Active Learning, Flipped classrooms are becoming the norm. The way students learn has changed. The "sage on the stage" or "chalk and talk" lecture styles is being replaced. Devices such as tablets (e.g. iPads) are changing the means by which educational content is distributed. Online textbooks can be updated easily and linked on the web to large numbers of related information sources. All this happens while the level of complexity of circuits and systems increases.

CAS educational pedagogy needs to keep pace with these innovations.

The goals of the workshop included:

1. Enhance teaching, learning, assessment and retention of CAS courses' knowledge for all students.
2. Exploration of links between communication theory and circuit theory and the new research issues in this area. Potential impact on the educational perspectives.
3. Develop and expand use of concept inventories (such as the Electric Circuits Concept Inventory-ECCI, Signals and Systems Concept Inventory-SSCI and Digital Logic Concept Inventory-DLCI) to stimulate assessment of important knowledge in CAS. Use the expanded concept inventories to improve the delivery of our CAS courses and demonstrate that this leads to improved learning outcomes for students.
4. Exploration of alternative pedagogies for Circuits, Analog and Digital Signal Processing and other Circuits and Systems courses.

One of the presentations was on simplification of circuit and systems (CAS) concepts of DC operating points and their role in circuit designs. This is important in the energy consumption of circuits and systems and they play a big role in the circuit design process and on circuit performance.

Online learning has taken off since major research universities such as Stanford, MIT, etc. have begun offering their courses online for free. Companies such as Coursera, edX, Udacity have sprung up and offered Massively Open Online Courses (MOOC's).

We had presentations on new pedagogies for the most basic courses in Circuits and Systems, e.g. Electric Circuits, Linear Systems, Digital Signal Processing, etc. We had a presentation on alternate pedagogies for teaching for the VLSI design course.

We also had panel discussions on the current and future role of Online learning in the delivery of the basic courses. There was a terrific presentation of lessons learned from MIT's edX Circuits courses presented both as traditional and as a MOOC. There are still some issues to be sorted out as to the impact of MOOCs on CAS education. It seems the jury is still out in this. However, there is no doubt that CAS education will be impacted by the technological landscape we find ourselves in as we move forward.

At the workshop, it was decided to publish some of the interesting presentations and other papers relevant to alternate pedagogies and approaches to circuits and systems education.



Some of the attendees at the CASEO Workshop in Beijing, China in 2013.

This special issue is the result of this decision. There are four papers in this issue. The first paper deals with the Use of Concept Inventories for CAS Education. The concept inventories are standardized assessment tools which have gained popularity because of their utility to help assess students' conceptual understanding with feedback to improve instructor teaching styles. The authors review the basic ideas and present examples from three concept inventories; Electric Circuit Concept Inventory (ECCI), Signal and Systems Concept Inventory (SSCI) and Digital Logic Concept Inventory

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(DLCI). Possible extensions to these are discussed and ideas for new concept inventories are presented.

The second paper discusses Multi-port Communication Theory. The authors provide a necessary framework to ensure that applications of signal processing and information theory actually do comply with fundamental physical laws such as the conservation of energy. This framework involves a circuit theoretic approach where the inputs and outputs of the communication system are associated with ports of a multiport black-box. Each port is described by a pair of two instead of just one variable, consistent with physics. The connection to information theory and signal processing is then obtained by means of isomorphisms between mathematical (formal) symbols of the latter and the physical quantities of the multiport model. The paper also includes a discussion of a number of interesting results of its application to single and multi-antenna radio communications in single- and multi-user contexts.

The third paper is an exploration of Chinese University curriculum and pedagogical perspectives on the teaching of the basic CAS courses. The focus here is on Peking University in Beijing China. The authors present some of the practices at undergraduate level, which have been developed in an attempt to make CAS education more appealing and effective. A review of the undergraduate curriculum is described with emphasis on CAS courses. A structured seminar class aims to create interactive learning space. Students are encouraged to practice in laboratories and in contests. The paper reviews the key challenges faced in implementing this curriculum. They describe existing CAS education at PKU and conclude with a look at future practices.

The fourth paper discusses using biometrics as a tool to teach design through a project based experience. This helps students learn open-ended project design skills and also further reinforces concepts in design, software skills, basic engineering and mathematics through vertical integration. This paper gives the project details, learning outcomes and assessment results of the design and implementation of biometric systems, namely, speaker, face and iris recognition.

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We sincerely hope you enjoy reading the articles in this special issue and welcome colleagues who are interested in joining the CASEO TC (see http://ieee-cas.org/community/technical-committees/caseo-tc).

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