this view, analysis becomes a justifiable detail. Part of this will require recognizing that electronics technology must be developed around leading-edge devices and on developing methods for gaining practical access to these technologies in both the lecture hall and laboratory of core courses. Part of this will require addressing the resource challenges associated with gaining access to current technologies and the development of laboratories that can practically use current components. Part of this challenge will be in recognizing that electronics now involves components or elements that are more than just transistors, gates, and op amps and that higher-level components such as data converters, phase-locked loops, and microcontrollers are now a part of many electronic systems.

A third challenge is in developing the instructional materials needed to support 21st century circuits and electronics courses. Materials are needed that focus on current technology and on relevant concepts and applications rather than dominantly on just analysis and low-level components.

A fourth challenge is in recognizing that some important concepts still require significant effort on the part of students to master and that if too much compression occurs, it will be difficult for students to master these concepts. For example, the concept of a Thevenin Equivalent circuit is likely still important and as simple as it may seem to be, it probably will take the student of 2010 just about as much time to master the concept as the student of 1950. A second is the concept of a nonlinear network and understanding how to both analyze and use nonlinear components. The concepts of noise, of the effects of environmental variations, and of the effects of statistical variations in components will still require considerable effort for students to master.

In summary, circuits and electronics education is currently in a state of flux in the US with continuing pressures to reduce emphasis on circuits and electronics in the core curriculum and with limited faculty experience and support for curriculum development in these areas. Opportunities, however, for applications of electronic devices will continue to grow and a large number of students that have a good understanding of current concepts in the circuits and electronics fields is necessary to take advantage of these opportunities. Although there are several challenges that must be addressed to provide the core circuits and electronics education that is needed of electrical engineering students of the future, these challenges can and should be addressed.

References

[1] D. C. Munson, "Elements of a new electrical engineering curriculum at Illinois: A shift from circuits to signal processing," in *Proc. IEEE Int. Symp. Circuits and Systems*, Apr. 1995, vol. 1, pp. 1Sf–4Sf.
[2] F. E. Terman, "Education in 2012 for communication and electronics," *Proc. IRE*, vol. 50, pp. 570–571, May 1962.

Josef A. Nossek

Region 8: Importance of Basic Principles

Circuit theory and design courses have experienced a reduction in EE/IT curricula over the last decades at most EE/IT departments. The courses that are still in place at a reduced amount of credits can be categorized either as electronic circuits or as system theory courses. In many electronic circuits courses, circuit tricks without much theory are taught while system theory basically is circuit theory, but without considering physical realizability conditions. Only at very few places circuit theory is still considered what it actually is: a model theory including physical realizabilty. It is central in structuring complex systems into functional building blocks (subsystems) and their interconnection. Such a structuring concept is vital for investigating highly complex systems and reveals a few very basic insights:

- Subsystems are interconnecting and communicate with each other via ports(terminal pairs).
- At each port there are always two variables present (current and voltage, incident and reflected waves, electric and magnetic field strength, . . .).
- Energy/power flow across ports is in general always described by two variables and not by the squared magnitude of one variable.
- Therefore, the concept of port is central not only for circuits, but for complex systems in general and especially in communications, control and signal processing.

These generic statements can be backed by a specific example. Let us consider multiple antenna communications systems (so called MIMO systems), a hot topic over the last decade in communication and information theory. A system with N transmit antennas and M receive antennas is in the information theory/communications literature usually described by an $M \times N$ channel matrix. But from a circuits point of view we of course know, that each antenna constitutes a port

Digital Object Identifier 10.1109/MCAS.2009.932195

and, therefore we have an (N+M)-port, which has to be characterized by an (N+M)×(N+M) matrix, may it be a scattering matrix, an impedance matrix, or whatever matrix may exist. Therefore, the common descriptions do not fully characterize the system and therefore may miss optimal solutions. Presently, we see already some contributions, where the mentioned problems are being addressed. The Circuits and Systems Society should take a lead in re-establishing the importance of the very fundamental concepts of circuit theory and design and regain an adequate role for circuits and systems in the curriculum.

It is not so much a question of circuits first or signal processing first, a discussion that is ongoing. There is lot of synergy to be gained between these areas by focussing on the basic principles. Therefore, a basic course in circuit theory already scheduled at the front end of the curriculum will be instrumental to educate the students, especially those who later will be the leaders in advancing solutions exploiting the physical limitations of technical systems.

Paulo S.R. Diniz

Region 9: Generating Motivation Among Students and Faculty

In Latin America, there are some traditional secondary and high schools that include in their programs strong emphasis on mathematics, physics, and science. However, many countries in the region struggle to provide widespread education to their young generations with rather limited resources. In some of them, like Brazil for example, many good quality model public schools became just average probably due to an effort to provide access to education to everyone, but with lower quality than the old model schools. Low wages and poor working conditions shy away potential good teachers to other activities. In the meantime, the private schools are becoming the choice of the medium and higher classes due to their higher quality.

At the university level, the public schools still attract the best students and host the best undergraduate and graduate level programs.

In Latin America, the best undergraduate schools receive very good students since most go through a tough selective process since the number of positions at high standard institutions is scarcer than in the developed world. As a result, the basic skills of the top engineering schools are usually quite good, and the Electrical and Computer Engineering (ECE) is no exception. However, a reduced interest of the students to learn circuits has been observed. Why is this happening? How deep should circuits be taught to electrical and computer engineers? How important is this knowledge to the engineer career?

There are many answers to these questions such as, among others: some students feel that knowing circuits will not help them get good jobs; circuits use more sophisticated mathematics than many other "interesting" topics; circuits is an old subject and includes old fashion laboratory experiments. In part, the truth is that most ECE programs have included many new courses in their curriculum by reducing the time available to basic concepts such as circuits, systems, and electromagnetism. The question is: Can one be considered an electrical and computer engineer without deep knowledge of these subjects?

The field of ECE consists of two main streams: applied physics and applied mathematics. It is then expected that a good professional should have a good grasp of the basics that compose the pillars of ECE, and circuits is no exception. Circuit analysis and synthesis is to say the least a wonderful tool to understand and design systems and verify their properties using the actual physical implementations.

Nowadays, there is a lack of depth and thoroughness in dealing with ECE basic concepts since the trend is to teach a number of topics in shallow manner whereas detailed learning is postponed to a later stage. Reasons why thoroughness is commonly avoided or postponed are because it requires competence, patience, and experience on the part of the instructor.

In most research-oriented universities around the world, the young and inexperienced assistant professors are required to be very productive in terms of research papers and to attract funding. This trend makes them less motivated to teach solid basic courses at undergraduate level. In this case, if the lecturer is assigned to teach courses not close enough to his research field, these courses tend to be superficial and informative, since they will not directly feed the

Digital Object Identifier 10.1109/MCAS.2009.932196