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References

[1] F. Terman, "A brief history of electrical engineering education," *Proc. IEEE*, vol. 64, no. 9, pp. 1399–1406, Sept. 1976 (Reprinted in Proc. IEEE, vol. 86, no. 8, pp. 1792–1800, Aug. 1998).

[2] W. L. Everitt, "Engineering education-circa 2012 A.D.," *Proc. IEEE*, vol. 87, no. 8, pp. 1397–1398, Aug. 1999.

[3] T. N. Trick, "Update on engineering education-circa 2012 A.D.," *Proc. IRE*, vol. 50, no. 5, pp. 571–572, May 1962 (Reprinted in Proc. IEEE, vol. 87, no. 8, pp. 1399–1403, Aug. 1999).

[4] R. Rohrer, "Taking circuits seriously," *IEEE Circuits Devices Mag.*, vol. 6, no. 4, pp. 27–31, July 1990.

[5] E. Guillemin, *Introductory Circuit Theory.* New York: Wiley, 1953.

[6] M. Van Valkenburg, "Teaching circuit theory: 1934–1984," *IEEE Trans. Circuits Syst.*, vol. 31, no. 1, pp.133–138, Jan. 1984.

[7] C. A. Desoer and E. S. Kuh, *Basic Circuit Theory.* New York, NY: McGraw-Hill, 1969.

[8] L. O. Chua, C. A. Desoer, and E. S. Kuh, *Linear and Nonlinear Circuits* (McGraw-Hill Series in Electrical Engineering: Circuits and Systems). New York: McGraw-Hill, 1987.

[9] W.-K. Chen, Ed., *The Circuits and Filters Handbook,* 2nd ed. Boca Raton, FL: CRC, 2008.

[10] T. Kailath, *Linear Systems.* Upper Saddle River, NJ: Prentice Hall, 1979.

[11] T. Bell and D. Dooling, *Engineering Tomorrow, Today's Technology Experts Envision the Next Century,* J. Fouke, Ed. IEEE Press, 2000.

[12] Y. Tsividis, "Some thoughts on introducing today's students to electrical engineering," *IEEE CAS Newslett.*, vol. 9, no. 1, pp. 1, 6–7, Mar. 1998.

[13] Y. Tsividis, "Teaching circuits and electronics to first-year students," in *Proc. IEEE Int. Symp. Circuits and Systems*, Monterey, CA, May/June 1998, pp. 424–427.

[14] Y. Tsividis, "Turning students on to circuits," *IEEE Solid-State Circuits Newslett.*, Jan. 2008.

Ljiljana Trajković

Regional Views and Experiences on Circuits and Systems Education

Teaching circuits courses to engineering students has been a topic of an ongoing debate over the past two decades. This debate continued during the Circuits and Systems Education Workshop held in conjunction with ISCAS 2008 in Seattle in May 2008. This contribution offers a collection of regional experiences and personal views presented at the CAS Education Workshop and at the Panel on Education in Circuits and Systems held at ISCAS 2008.

The contributions presented in this article by prominent educators in four distinct geographical areas address various issues relevant to CAS education and offer views and recommendations. The authors address current status of CAS education in each geographical region and offer suggestions for future improvements. While based on the presented material, opinions given in this contribution may have evolved based on the discussions held during the workshop. These suggestions also indicate ways how the CAS Society may help and get involved by developing valuable teaching tools and by sponsoring and encouraging educational projects and outreach programs.

A variety of topics is addressed, approaches debated, and remedies offered. They include:

- *General approach*: Basic circuits vs. digital signal processing (DSP first) debate and experiences from the Georgia Tech and the UC Berkeley experiments.
- *Targeted audience*: Need to design tailored circuits courses for a variety of engineering students with distinct majors.
- *Choosing the right text*: Finding the right text for a course among a myriad of available textbooks.

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- *Laboratories*: Exercises designed to illustrate application of the theory taught need to reflect modern technological advances and be fun for students.
- *Software tools*: SPICE and MATLAB are supplemental tools and are employed for better understanding of the theory taught.
- *Course instructors*: Teaching circuits as service courses by unmotivated instructors and faculty with other research interests.
- *Presentation styles and delivery*: From blackboard to overhead projectors to PowerPoint sides and back to the whiteboard.
- *Recruiting future engineers*: Reaching out to high-schools and motivating future engineering students.

General approach: Past offerings of basic circuits courses to undergraduate engineering students usually consisted of two lower level undergraduate courses (Basic Circuits I and Basic Circuits II) that cover basic circuit theory. While early offerings of such courses covered topics that included graph theoretic approach to writing circuit equations, this approach has been long abandoned and students are now exposed to only elementary notions of graph theory. Rarely will one see offerings of advanced topics in circuit theory or a course dealing with nonlinear circuits and systems. In mid 90's, Georgia Tech and UC Berkeley departed from classical approach to teaching circuits by introducing "Digital Signal Processing First" and "Structure and Interpretation of Systems and Signals" courses.

Targeted audience: Engineering student majors come in a garden variety including: electronic engineers, computer engineers, bioengineers, and mechatronics majors. Not all will be circuit designers and many may benefit from circuits courses carefully tailored to fit program-specific curricula that match their scientific interests and needs.

Choosing the right text: There is a variety of basic circuits textbooks available on the market. The "cookbook" approach offered by a myriad of textbooks available in our bookstores (at a hefty price) may not be serving future electrical engineers well. Student feedback seems to favor recommended texts only rather than a specific required text, with a variety of textbooks and other resources placed on Library reserves.

Laboratories: Exercises are designed to illustrate application of the theory taught, reflect modern technological advances, and should be fun. The open laboratory model (24/7) is often preferred by undergraduate students. In cases when the laboratories are combined with lectures, five laboratories per term seem adequate. Examples of more advanced laboratories offered in the first circuits course (taken during the second year of undergraduate curriculum) include building a sample radio and testing the signal reception, designing and building an active low-pass Butterworth or Chebyshev filter to meet given specifications required in the second circuits course (taken during the third year of undergraduate curriculum), and a more senior final project in case of an advanced circuits course.

Software tools: Tools such as MATLAB and SPICE have become common aids to complement lectures, tutorials, and laboratories. These supplemental tools are used for better understanding of the theory taught. However, circuit simulation tools require adequate introduction to be helpful in various laboratory experiments.

Course instructors: Teaching circuits as service courses by unmotivated instructors will hardly generate students' enthusiasm. At many schools, circuits courses are taught by sessionals and instructors as a service to the department and are often viewed as a "chore" or even a "punishment". If taught by more senior faculty, their research interests are often in areas not related to circuit theory and/or circuit design.

Presentation styles and course delivery: The advancement of various computer-aided presentation tools had limited success in departing from classical tools and we have made the full circle from using the blackboard to overhead projectors to PowerPoint slides and back to the whiteboard. Various communication tools exist for use outside of lecture halls and have become important educational media (web pages, notes, handouts, audio recordings of lectures, design examples from industry, puzzles, and email messages). Good quality textbook supplements (master slides, tutorial problems, solution manuals) are, in general, unavailable from the publishers. There is a need for tutorials, video-taped lectures, educational games, design kits (similar to kits offered by National Instruments), public lectures and demos (such as the exciting keynote talk by John Cohn delivered at ISCAS 2008), and IEEE.tv, YouTube, and MySpace presence.

Recruiting future engineers: Reaching out to high-school students by organizing visits to engineering labs, engineering days, summer camps, and summer work programs elects interest to pursue engineering: high school work programs, summer co-op programs for undergraduate students sponsored by funding agencies, and international summer training programs (an example is the program at the L'Institut des Sciences de l'Ingénieur de Toulon et du Var, ISITV) is important.

In closing and looking forward, if we wish to generate interest in circuits among the incoming engineering students, we need to do a better job of promoting the profession by:

- providing betters teaching tools and delivery methods

- combining circuit theory courses with laboratory exercises
- illustrating the application of circuits in fields relevant to environment, biotechnology, medicine
- recognizing and rewarding teaching circuits courses
- doing a better job in sharing our enthusiasm for the engineering profession.

References

[1] R. Rohrer, "Taking circuits seriously," *IEEE Circuits Devices Mag.*, vol. 6, no. 4, pp. 27–31, July 1990.
[2] Y. Tsividis, "Some thoughts on introducing today's students to electrical engineering," *IEEE CAS Newslett.*, vol. 9, no. 1, pp. 1, 6–7, Mar. 1998.
[3] Y. Tsividis, "Teaching circuits and electronics to first-year students," in *Proc. IEEE Int. Symp. Circuits and Systems*, Monterey, CA, May/June 1998, pp. 424–427.
[4] Y. Tsividis, "Turning students on to circuits," *IEEE Solid-State Circuits Newslett.*, Jan. 2008.

Randall Geiger

Regions 1-7: Circuits and Electronics—the Past, Present, and Future?

Circuit theory and electronic circuits were the centerpiece of an electrical engineering education throughout the middle of the last century with some of the greatest engineers of the 20th century focusing on electrical and electronic circuits. By the 1970's, some of the more advanced courses in the circuits/electronics field started to disappear from the required curriculums. In the 1980's, curriculum pressures to add newer topics to support digital and computer systems started to put pressures on lower-level circuits and electronics courses that had been part of the core electrical engineering curriculums for many years. Through the 1990s, many schools made a significant reduction in the number of credits associated with core circuits and electronics courses. In the 1990's, drops in a typical core curriculum from a one-year circuits sequence and a one-year electronics sequence and possibly a more advanced course to a one-semester circuits course and a one-semester electronics course were common with some schools reducing the circuits/electronics emphasis even more. At my own institution, over a 10-year period starting in the mid 1990's, we saw a drop in the core circuits/electronics curriculum from 19 semester credit hours1 (cr.hr.) to 8 semester cr. hr. and are now trying to assess whether this drop was too much or too little. In the mid 1990's, a new curriculum discussed by Dave Munson [1] at the University of Illinois, a school that was noted for many years to have some of the best minds in the circuits and electronics field, shows no electronics or circuits courses in the core. Instead, some of the material that was covered in the circuits courses in the past was included as part of a 4 cr. hr. course in analog signal processing. Munson reported that some of the rationale behind this change is due to the observation that "Incoming students now have experience with complex electronic systems, where the individual components are inaccessible. These systems are typically computers or consumer electronics equipment, which process audio and video signals. There are few discrete components. Incoming students have not built computers, VCRs, or CD players, as students used to build crystal radios. Furthermore, circuit analysis *per se*, is now practiced by only a miniscule number of hot-shot circuit designers, who in turn use CAD software developed by a small number of colleagues".

Paralleling the drop in emphasis on circuits and electronics in the core curriculums is a near absence of faculty members that have been trained in the circuits/electronics field. Few colleges or universities have hired tenure-track faculty members in the last 30 years for their expertise in circuits or electronics and almost all of those faculty members that have a strong training in the circuits/electronics fields have now retired. There is almost no research funding available in the U.S. in the circuits or electronics field making it difficult for faculty members to devote time to developing these fields. There is an almost universal perception that "ANYBODY CAN TEACH" circuits courses or electronics courses and it is not uncommon for a teaching assignment of a circuit analysis course or an electronic circuit analysis course to be an unwelcome outcome associated with teaching performance or research performance in the area of specialization of a faculty member dropping to an unacceptably low level or the consequence of an individual becoming dispensable in his/her area of core competence. Whereas in the past, most faculty members had at least a strong undergraduate background in circuits and electronics, this background is now lacking in many faculty members as well. Most of the more popular textbooks for circuits courses and electronics courses have been around in various editions for over two decades as well and many of the authors of these books have either retired or are nearing retirement. Of necessity, these textbooks

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are written for adoption by "ANYBODY CAN TEACH" instructors. As Munson [1] correctly observed, there are few discrete components used in systems today, yet electronics and circuits laboratories are invariably based upon components of the 1970's that are becoming increasingly difficult to even locate. This should raise serious questions about whether the materials that are being presented are still relevant. Aside from the discrete components, there are also some concerns about the integrated components that are available to support undergraduate electronics instruction in the US. The widely-used MOSIS program has provided access to integrated circuit technology since the early 1980's. At the time this program was started, the technology available to students was at or near the state of the art technology used by industry. Today, the only widely-available semiconductor process suitable for use in undergraduate laboratories is the 0.5 μm CMOS technology. With industry now developing products at the 22 nm technology node, the 0.5 μm technology is 8 generations behind the state of the art.

Student attitude in circuits and electronics courses is often also a problem with many students expressing a sense of boredom and a lack of motivation for the circuits and electronics field. But this should not be surprising considering the reduced emphasis that is being placed on circuits and electronics, the general attitude about the importance of electronics and circuits conveyed by the faculty, the selection of faculty members to teach these courses, the motivation of instructors who are often not in their classroom of choice, the outdated technology that is being used in the laboratories, and the concerns about the relevance of these materials in today's electronic systems.

In 1962, Frederic Terman, a visionary at a time when most curriculums had a major emphasis on circuits and electronics, published a paper making a bold 50-year prediction about electrical engineering education of the future. In this paper he observed "… it is safe to predict that the subject of electronics will be even more important within the university in 2012 than it is today, that the importance of the leading professors in the field will be greatly enhanced, and that educational institutions with strong graduate programs in electronics will be regarded as great economic plums because of this fact".

The impact of electronics technology today on society is consistent with Terman's vision with nearly 20% of the price of an automobile going to electronics, with a semiconductor industry that is approaching $300 Billion in annual sales, and with electronic technology embedded in cell phones, computers, biomedical equipment, and a host of other products. Opportunities for electronics technology growth in the next 50 years will dwarf what we have seen in the previous 50 years. Although I will not attempt to predict where this growth will occur, at least some of it will be at the interface between electrical and biological systems, some of it will support biomedical technology that few even envision today, and some of it will be associated with sensor interfaces to physical systems. Those individuals that will play a lead role in developing the concepts that will emerge into products and those that play a lead role in developing and marketing products will have a strong fundamental understanding of circuits and electronics. In contrast to the comments of Munson that suggest that only "a miniscule number of hot-shot circuit designers" will use CAD tools to design the electronic systems of the future, I believe that a large number of engineers that have strong skills in circuits and electronics and that are empowered with good CAD tools will be needed to lead this technology development. Consistent with the philosophy of Louis Pasteur "Chance favors the prepared mind", recognizing opportunities for developing future generations of electronic products will require a firm understanding of circuits and electronics.

There are major challenges facing the future of education in the circuits and electronics fields in the US and how these challenges are collectively addressed will play a key role in determining the presence of US companies in the future of the microelectronics industry. I will identify a few of the most important.

One of the biggest challenges is the academic institutions themselves which are self-perpetuating and which are now nearly void of individuals with strong backgrounds in circuits and electronics that can serve as advocates for developing the field. A part of this challenge will be recognizing that an "ANYBODY CAN TEACH" instructor for circuits and electronics courses will likely not provide the type of education needed. A part of this challenge will be in hiring individuals that really are well-suited to play a lead role in circuits and electronics education. A part of this challenge will be in recognizing that it is important to convey the big picture of the circuits and electronics fields to the students so that they can see where applications, opportunities, and challenges lie. A part of this challenge is in providing space in a curriculum that is already under pressure for inclusion of other topics. And, a part of this challenge is in recognizing the difference between dated or obsolete materials that have been appropriately de-emphasized and current materials or approaches that are relevant.

A second challenge is in making changes to the fields of circuits and electronics so that these disciplines can be aligned with emerging technologies rather than technologies of the past. Part of this will require recognizing that the field of circuits should not be viewed as circuit "analysis" but rather must focus on understanding how circuits operate and interface with the world in which we live. With 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

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and, therefore we have an (N+M)-port, which has to be characterized by an $(N+M)\times(N+M)$ 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

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research activities. As a result, in the long run the curriculum of these universities might evolve to attend the research interests of the faculty instead of providing a broad and long-term foundation to the future engineers.

However, there are a number of universities where research is not a requirement and where what matters is the number of hours the instructors spend teaching in classrooms. In this case, the question is what is gained by providing depth and how to keep the teachers motivated and updated.

For ECE in any region of the world, I believe that a deep knowledge of circuit analysis ranging from Kirchhoff's Laws to computer-aided analysis of nonlinear circuits is essential. However, new ways to motivate and teach this subject should be created and implemented via new concepts for textbooks and with the aid of skilled teachers and experiments.

Yong Lian

Region 10: Designing Circuits Curriculum and Following Good Practices

Circuit design courses often do not seem to be the most attractive choices for the engineering students. This is largely due to the initial complexity of mathematics needed for introduction of basic concepts that tends to cause problems and reduces the motivation of some students. The necessity of dealing with hardware components and various measurement equipments becomes yet another obstacle for many students. In general, the younger generation seems to prefer software tools instead of hardware. However, the importance of circuit design, especially design of integrated circuit (IC), has grown to a level that it becomes an essential part of many new applications. Understanding circuits and systems (CAS) and having a thorough grasp of the subject will be a great benefit to engineering students, especially for those who wish to become IC designers. This calls for innovative ways to teaching CAS in universities.

In general, the CAS education in Region 10 follows the traditional curriculum design, i.e., continuous-time systems are introduced before discrete-time systems and circuits and systems are covered in various modules. This helps students build a solid foundation in both circuits and systems. Most CAS related courses contain laboratory sessions and/or computer simulations in addition to classroom teaching. Some universities include design projects to establish connections between theory and applications. Lecturing is the most common mode of classroom teaching although project or problem based learning is used in some universities. This is mainly due to the large class sizes and high student to staff ratio in Region 10. Although the current practices seem to work well, the following observations may help improve the CAS education:

- Computer simulation tools should not be introduced to students at the beginning. Design and analysis skills on paper shall be taught first together with well-designed assignments and lab sessions. The assignments help students understand the concepts taught in the classroom while experiments allow students to verify the topics learnt from the textbook. The simulation tools such as SPICE, Matlab, and EDA tools should be introduced to student at later stage. This is because many students taking the circuit courses rely heavily on EDA tools for circuit design. They tend to believe that the best solution results from numerous simulations with a variety of parameter setting. This is quite common approach among students who are exposed to computer simulations at early stage of circuit design.
- The circuit design course should be taught by instructors with few years of IC design experience or an active researcher in the field of CAS. The circuit design involves the trade-offs within the design space, especially for analog circuit design, and requires the understanding of devices and CMOS process. These skills and knowledge should be imparted to students at the early stage of circuit course. It is difficult to achieve this goal by following the prescribed textbook if the faculty does not have experience in IC design or is involved in CAS related research.
- Design projects that cover the full IC design flow make substantial differences in training students. Such a course covers the circuit design, simulation, layout, verification, chip fabrication, circuit

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assembly, and chip measurement, and runs over two semesters. In the first semester, students are divided into small groups of three to four students. Each group works on a given analog or mixed-signal design project that covers schematic capture to GDS-II generation. The chip is sent to fabrication before the semester break and is ready at the beginning of the second semester. In the second semester, the students work on the PCB design, assembling designed circuits, chip measurement, and report writing. The course covers not only circuit design but also other engineering issues related to applications.

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