



Teaching and Learning for New Generations of Engineers

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SCUT, Guangzhou, China, July 8, 2011



Roadmap

- Introduction
- Case Studies: Engineering Program at Simon Fraser University
- Undergraduate Courses:
 - Electric Circuits I and II
 - Communication Networks
- Graduate Courses:
 - Special Topics in Theory, Analysis, and Simulation of Nonlinear Circuits
 - Communication Networks
- Conclusion: Lessons Learned



Introduction

- Understanding systems is fundamental to engineering and continuing to offer courses in theory and applications of systems to new generations of engineering students remains an important part of any engineering curriculum.
- Attracting new generations of students to systems is a challenging task that calls for new approaches, methodologies, and projects that will appeal to current generations of both educators and students.
- Designing these new tools and making them freely available to educators is an important step in eliciting renewed interest in engineering.



Motivation

- Providing students with a solid theoretical background greatly improves their ability to solve a variety of practical engineering problems.
- National institutions have recognized the need for improving engineering education.
- Attracting the best students to engineering programs and eliciting their interest to circuits courses has been also subject of a number of ongoing debates over the past two decades.

National Science Foundation, Moving Forward to Improve Engineering Education, NSB-07-122, Nov. 19, 2007.



Engineering options

- Current engineering programs offer a number of majors:
 - electronic
 - computer
 - bioengineers
 - mechatronics
- These programs may need circuits courses carefully tailored to fit a program's specific curricula.
- The “cookbook” approach may not be serving future electrical engineers well.
- Lectures, tutorials, and laboratories are often supplemented by software tools such as MATLAB, SPICE, OPNET, and ns-2 to enhance understating of the theory taught.



Presentation styles and delivery

- From blackboard to overhead projectors to PowerPoint slides and back to the whiteboard.

Communication tools:

- Web pages, online notes, electronic handouts, audio recordings of lectures, examples from industry, fun exercises and puzzles. And endless stream of email messages
- Presentation styles and delivery are often enhanced by good textbook supplements: master slides, tutorial problems, solution manuals.
- Ongoing demand for new tutorials, video-taped lectures, educational games, design kits, fun and motivational lectures, and online content.



Course instructors

- In many engineering departments, service courses are considered to be service courses.
- They are often taught by sessionals and instructors as a service to the department.
- These instructors are often unmotivated and can hardly generate students' enthusiasm.
- More senior faculty teaching service courses often have their research interests in areas not related to circuit theory and/or circuit design.
- Lack of industrial experience often deprives instructors from appreciating the importance of practical applications in engineering education.



Engineering program at SFU: Electric Circuits

- School of Engineering Science offers two classical undergraduate courses in electric circuits. These courses are offered to second and third year students.
- SFU follows trimester system (three terms per calendar year) and each term lasts thirteen weeks.
- There are weekly homework assignments and the midterm and final examinations.
- In addition to three-hour lectures per week, one-hour tutorials offered weekly for the undergraduate courses deal with solving analytical problems.
- The undergraduate courses have laboratory components and students are expected to submit written laboratory reports. The School follows the 24/7 open-laboratory model.



Engineering program at SFU: Electric Circuits

- There is no required textbook. Several textbooks are recommended. A large number of textbooks and references are made available through the University Library reserves.
- Occasionally, a course in nonlinear circuits is offered to senior undergraduate and graduate students as a special topics course.
- There are weekly homework assignments, two short midterm examinations, and a final research project.

Laboratory



SCUT, Guangzhou, China, July 8, 2011



First course: Electric Circuits I

<http://www.ensc.sfu.ca/~ljilja/ENSC220/>

- The first course in electric circuits deals with elementary concepts and analysis tools.
- The course pre-requisites are two first year physics courses and the course co-requisites are two second year mathematics courses.
- This course is a pre-requisites for undergraduate courses in electronic devices and microelectronics.



First course: Electric Circuits I

Topics:

- Circuit elements
- Kirchhoff current (KCL) and voltage (KVL) laws
- Operational amplifiers (op-amps)
- Circuit analysis techniques
- Thevenin and Norton theorems
- First order circuits
- Second order circuits
- Sinusoidal steady-state analysis
- AC power
- Polyphase circuits



Electric Circuits I laboratories

- Lab bench orientation:
 - Part 1, Power supply and digital multimeter
 - Part 2, Function generator and oscilloscope
- Lab 1, **KCL** and **KVL**
- Lab 2, **Op Amp**
- Lab 3, **RL** and **RC** circuits.
- Lab 4, **RLC** circuits
- Lab 5, **AM radio** demo



Second course: Electric Circuits II

<http://www.ensc.sfu.ca/~ljilja/ENSC320/>

- The second course in electric circuits is intended to enhance the knowledge of students in the area of electric circuits and to further develop their analytical skills.
- The course pre-requisite is the first course in electric circuits.

Topics:

- Analysis of circuits in the time domain
- Laplace transform
- Frequency response, filters, and resonance
- Filter design
- Mutual inductance and transformers
- Two-Port networks



Electric Circuits II laboratory

- The laboratory exercise deals with the design and implementation of an active filter.
- The students are asked to design a low pass filter for telephone speech signals that have bandwidth of 300–3,400 Hz.
- The filter is to be used to suppress interference by attenuating interference signals by at least 30 dB starting at 11 kHz.
- The telephone signal should not be attenuated more than 0.5 dB. Students are given the laboratory assignment and the instructions early in the trimester:

Lab report:

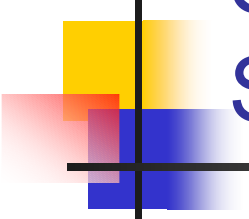
- Describe your design and the performance of your implementation. Explain differences between your expectations and the actual filter performance.



Electric Circuits II laboratory

Design:

- Examine Butterworth and Chebyshev filter realizations that meet the specifications.
- Plot frequency responses using MATLAB. Select the most appropriate filter type, order, and filter parameters.
- Design the filter using Sallen-Key stages with an overall gain (output voltage/input voltage) in the range 2 to 3.
- Simulate your design using PSPICE.
- Build the filter circuit, test it, and compare its performance to the specifications and to PSPICE predictions.



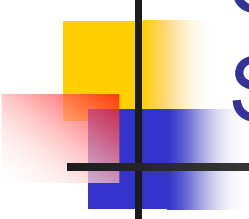
Graduate Course: Special Topics in Theory, Analysis, and Simulation of Nonlinear Circuits

<http://www.ensc.sfu.ca/~ljilja/ENSC895/>

- This is a research oriented graduate course in nonlinear circuits.
- The course aims to provide insights and understanding of complex static and dynamic behavior of circuits consisting of bipolar and MOS transistors.

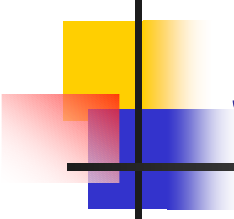
Topics:

- Global properties of electronic components, properties of nonlinear circuit equations, existence and uniqueness of dc operating points, stability of operating points and the occurrence of bistability, methods for computing solutions to dc, ac, and transient circuit equations, homotopy methods for finding such solutions and their software implementations.



Graduate Course: Special Topics in Theory, Analysis, and Simulation of Nonlinear Circuits

- Emphasizes is given to the relationship of circuit theory to circuit design and its usefulness in practical applications.
- Students are introduced to various theoretical approaches and numerical methods for analyzing nonlinear electronic circuits.
- The course pre-requisites are undergraduate courses in electric circuits, electronic devices, microelectronics, and a first course in linear algebra.



Graduate Course: Special Topics in Theory, Analysis, and Simulation of Nonlinear Circuits

Graduate research projects

- A final research project is an important component of the course. Software tools such as MATLAB and PSPICE are used for circuit simulations.
- **Sample projects:**
 - Stimulations of negative resistance circuits
 - Analyzing stability of nonlinear circuits
 - Computing dc operating points of nonlinear circuits
 - Analysis, modeling, and design of an IGBT-based power converter.



Engineering program at SFU: Communication Networks

<http://www.ensc.sfu.ca/~ljilja/ENSC427/>

- This course covers the techniques needed to understand and analyze modern data communications networks.
- It covers the basic architecture of packet networks and their network elements (switches, routers, bridges), and the protocols used to enable transmission of packets through the network.
- Quantitative performance analysis and design of data and integrated services networks.
- Re-transmission error recovery schemes, networks of queues, congestion control, routing strategies.
- Multiple access techniques in data networks, design for specified throughput and delay performance.



Engineering program at SFU: Communication Networks

- Wireless networks, routing approaches in mobile networks.
- Analysis and design of broadband integrated services digital networks, asynchronous time division multiplexing.
- Laboratory work is included in this course.
- This is a project oriented undergraduate course. Students will be introduced to the OPNET (OPNET Technologies) tool for simulating packet networks.
- The course pre-requisite is successful completion of ENSC 327-3 or permission of the instructor.



Engineering program at SFU: Communication Networks

Topics:

- Communication networks and services
- Application of layered architecture
- Digital transmission fundamentals (overview only)
- Circuit-switched networks
- Peer-to-peer protocols and data link layer
- Medium access control protocols and local area networks
- Packet-switched networks
- TCP/IP



Engineering program at SFU: Communication Networks

[http://www.ensc.sfu.ca/~ljilja/ENSC427/Projects/
ENSC427_Spring2011_projects.html](http://www.ensc.sfu.ca/~ljilja/ENSC427/Projects/ENSC427_Spring2011_projects.html)

Sample projects:

- Exploring traffic for P2P file sharing protocol using OPNET
- Comparison and analysis of FIFO, PQ, and WFQ queuing disciplines using OPNET
- Analysis of Quality of Service (QoS) on broadband over powerline and power line communication networks via OPNET
- Voice over Internet protocol (VoIP) over 3G network
- Analysis of live video streaming over BitTorrent peer-to-peer protocol



Engineering program at SFU: Communication Networks

Sample projects (cont.):

- Video streaming over the 802.11g and the 802.11n WLAN technologies
- Video streaming over WiMAX
- Analysis of video surveillance over WiMAX networks
- Examining wireless mesh network routing protocols through simulation
- Improved ant routing for wireless ad-hoc mesh networks
- Analysis of BitTorrent



Graduate Course: Communication Networks

<http://www.ensc.sfu.ca/~ljilja/ENSC835/>

- This course covers the techniques needed to understand and analyze modern data communications networks.
- It covers the basic architecture of packet networks and their network elements (switches, routers, bridges), and the protocols used to enable transmission of packets through the network.
- It addresses techniques for collection, characterization, and modeling of traffic in packet networks.
- It covers aspects of traffic management, such as various call admission control and congestion control algorithms in high-speed packet networks and the influence of traffic on network performance.



Graduate Course: Communication Networks

<http://www.ensc.sfu.ca/~ljilja/ENSC835/>

- This is a project oriented graduate course. Students will be introduced to various algorithms and software tools for simulating packet networks:
 - OPNET (OPNET Technologies),
 - ns-2 network simulator (Lawrence Berkeley Labs)
 - Ptolemy (UC Berkeley)
 - AutoClass (NASA)
 - S-PLUS (Insightful) tool for statistical analysis
- The course pre-requisites is successful completion of ENSC 427-3 or permission of the instructor.



Graduate Course: Communication Networks

Topics:

- Computer networks and the Internet
 - history and networking principles
 - network services and organization
 - network protocols (Ethernet, Internet, Token rings, FDDI)
 - circuit-switched networks
 - packet-switched networks (wired, wireless, Internet, ATM)
 - switching, scheduling, naming, and addressing, routing, error control, flow control.
- Introduction to simulation tools for evaluating network performance
 - OPNET: tutorial and case studies (GPRS, M-TCP)
 - ns-2: tutorial and case studies (mapping the Internet)



Graduate Course: Communication Networks

Topics:

- Application Layer
 - case study: Gnutella
- Transport Layer
 - case study: modeling TCP/RED
- Network Layer
 - case study: analysis of BGP
- Link Layer and Local Area Networks
- Analyzing Internet topology
- Wireless and Mobile Networks
 - case study: M-TCP, TCP+
- Traffic collection, characterization, and modeling



Graduate Course: Communication Networks

[http://www.ensc.sfu.ca/~ljilja/ENSC835/Projects/
ENSC835_Spring2011_projects.html](http://www.ensc.sfu.ca/~ljilja/ENSC835/Projects/ENSC835_Spring2011_projects.html)

Sample projects:

- Mobile IP versus IPsec tunneling with MOBIKE: a comparison under wireless vertical handover
- Comparison of WiMAX and ADSL by streaming video content using OPNET
- Coordination of mobile WiMax(802.16E) with WiFi technology
- Simulating General Packet Radio Service (GPRS) using OPNET
- OSPF, EIGRP and RIP performance analysis based on OPNET
- Modeling and simulating STP vs. RSTP on various network topologies



Graduate Course: Communication Networks

Sample projects (cont.):

- Analysis of mobile IP in wireless LANs
- Performance evaluation of Key 802.11 MAC protocols
- Creating profile for small and large networks



Additional resources

- The entire course material is available online.
- Course web pages contain links to homework assignments, laboratory exercises, and supplementary references.
- Topics to be covered in class are posted weekly
- Each course lecture is audio recorded and these recordings are made available shortly after each lecture to students enrolled in the course.
- Puzzles and games



Conclusions and lessons learned

- School of Engineering Science at SFU offers a **five-year** undergraduate program in engineering.
- The program is **highly ranked** among the comprehensive Universities in Canada.
- However, many students are entering the engineering program **without** having necessary **mathematical background** and **analytical skills** to excel and enjoy the subjects taught.
- **Changing** undergraduate engineering curriculum to adopt **new approaches** to teaching circuits is a difficult task.
- The **curriculum** already contains a **large number of required courses**, which leaves little room for implementing desired changes such as, for example, offering separate laboratory courses as a follow-up to lecture-intensive courses in circuits.



Conclusions and lessons learned

- **Attracting students** to take engineering courses and motivating them to complete these courses is an essential component of teaching the course.
- **Very early** in the trimester, **simple examples** of electronic components (diodes, nonlinear resistor, op-amps, and transistors) are used **to illustrate modeling circuits** and to emphasize that linear circuits are only an approximation of electric and electronic elements.
- **Examples** employing **linear op-amps** are then used to introduce various linear analysis methods.
- **Early exposure** to **software tools** such as MATLAB and PSPICE provides a valuable complement to analysis. The analytical and simulation results are then confirmed by laboratory measurements.



Conclusions and lessons learned

- Feedback received from students indicates that majority of current undergraduate students find the circuits courses **difficult** and **demanding**.
- Past experiences with choosing a variety of textbooks showed that **almost any of the textbooks would prove adequate**. More important was the delivery of lectures, selection of topics covered, choice of assignments and examination questions, and quality of the laboratory equipment.
- Students overwhelmingly **enjoyed** having **laboratory** exercises and course projects, which they often complete by working in teams of two or three.
- Such laboratories, however, should be **properly maintained** and **equipped**.



Resources

<http://teaching.berkeley.edu/compendium/>

(first published in 1983)

A Berkeley Compendium of Suggestions for Teaching with
Excellence

Barbara Gross Davis

Lynn Wood

Robert C. Wilson

Resources

<http://ctl.stanford.edu/>

Center for Teaching and Learning

Effective Teaching, Effective Learning, Effective Speaking



- In its broadest terms, our purpose is to promote excellence in teaching at all ranks and excellence in student learning inside and outside the classroom.
- Our goal is to see teaching equally valued with research as a professional commitment of faculty and teaching assistants and to provide the training and resources to make excellent teaching possible.
- Effective teaching encompasses more than just the transmission of subject matter, however.



Resources

- Excellent teaching, first of all, gains the students' attention and convinces them of the importance of what is being taught and learned.
- It goes on to communicate not only information and concepts but to develop powers of analysis, synthesis, judgment, and evaluation, all in a context of considered values. When teaching has truly succeeded, students leave with an ability to learn, question, and commit on their own.
- Our goals for student learning are complementary—that students not settle for just learning the “stuff” or enough “stuff” for a decent grade.
- They should be training their minds and sensibilities for a lifetime responsibility of critical, independent thought and commitment to personal and community goals.
- They should have high expectations of their own efforts and of their teachers' efforts.
- They should see learning as extending far beyond the classroom to most of what they experience.



In closing and looking forward

If we wish to generate interest among the incoming engineering students, we need to do a better job of promoting the profession by:

- providing **bettors teaching tools** and delivery methods
- **combining** theory courses **with laboratory** exercise
- **illustrating** the **applications** in fields relevant to environment, biotechnology, and medicine
- **recognizing** and **rewarding teaching**, and
- doing a better job in **sharing our enthusiasm** for the engineering profession.



Embracing a new paradigm: experiential learning

Experiential learning is the process of making meaning from direct experience.

Aristotle:

”For the things we have to learn before we can do them, we learn by doing them”