Specialization Profile: Computer Engineering

by Dr. Bart Sinclair

Introduction - Computer engineering focuses on the design, analysis, and implementation of computing and other digital systems and devices, from large computing clusters, through mobile battery-powered embedded systems, to novel nano-devices. Computer engineers design the hardware that is at the core of information technology, and the use of information technology is ubiquitous (try to figure out how many computing devices are in a modern car, for instance). Research at Rice focuses on a wide range of devices, systems, and tools, covering everything from computer-aided design (CAD) to application specific software and hardware.

Technology trends – smaller feature sizes, lower voltage levels, higher operating frequencies – are projected to cause an increase in the soft error failure rate in integrated circuits. While memories have historically been the focus for soft error failure rate reduction, recent studies indicate that the soft error failure rate in logic will also increase. Research is ongoing in the development of CAD tools to reduce the soft error failure rate in logic circuits. Additionally, the advent of the nanometer regime has introduced new challenges in designing integrated circuits: manufacturing process variation, electrical signal integrity, and thermal effects that tend to limit the expected performance gain.

At Rice, we investigate, develop and implement innovative automated design solutions for digital, analog/RF and mixed signal systems and devices for embedded systems, sensor networks, and emerging applications in nanotechnology and biomedical engineering. As we move from devices to systems, parallel I/O is a necessary component of modern Web and database servers, high performance computing, and data-intensive applications such as multimedia retrieval, visualization and graphics, scientific simulations, and spatial and geographic databases. Parallel hardware storage systems with multiple disks and high-bandwidth switched interconnect are becoming increasingly available to fill this need. Finally, the rapid advances in very large scale integration (VLSI) technology have allowed computer engineers to build both general-purpose processors for supercomputers and personal computers and special-purpose processors for communications, signal processing, and robotics. Many of these applications involve a core group of matrix computations that can be efficiently performed on parallel arrays of arithmetic units. Research on these algorithms and their efficient mapping to low-power architectures is leading to new digital signal processing (DSP) and Application-specific Instruction Processor (ASIP) architectures.

Hot Topics in Research

Nano-electronics - New devices and processes to build the next generation of integrated circuits beyond current CMOS silicon transistor technology.

Variation-tolerant circuit design - As device sizes shrink to nanometers, it is critical to build reliable systems that are both low-cost and high performance.

Low power design - Battery capacity is not growing as rapidly as the number of transistors on a chip or clock rates, both of which increase the power demands of digital devices. New design techniques are needed for mobile systems (laptop or notebook computers, cell phones, PDAs, portable entertainment devices). Area, time, power, and data rate constraints all need to be jointly optimized to extend battery life.

Systems on chip - Processors, memories, radios, sensors and actuators can all be integrated and combined on a single chip to increase performance and reduce size. Applications range from sensor networks to cell phones to health care.

Reconfigurable computing - Computer systems can be continuously updated and modified after being built through the use of field programmable gate arrays (FPGA). This allows for both rapid prototyping of new systems and real-time adaptation as workloads change in mobile computing and communication systems.

Rice University - **Learn about some of the topics professors at Rice are investigating right now.**

• Defect and fault tolerant computing for sub-100nm and nano-electronic designs
– Dr. Kartik Mohanram

• Analog/Mixed-Signal Design Automation for System-on-Chip Technology
– Dr. Yehia Massoud

• Low power embedded systems
– Dr. Kartik Mohanram, Dr. Yehia Massoud, Dr. Joseph Cavallaro, Dr. Lin Zhong

• High Performance Parallel I/O
– Dr. Peter Varman

• VLSI signal processing architectures
– Joseph Cavallaro

What are some good classes?

- - Elec 327 (Implementation of Digital Systems), Elec 422 (VLSI Design), Elec 425 (Computer Systems Architecture), Elec 428 (Computer Systems Performance)

What are some helpful outside areas of study?

- - Optimization theory, numerical analysis and simulation, device physics, digital signal processing, probability

What are some ways to get hands on experience?

- - Summer research with faculty, summer internships with ECE industrial affiliates, volunteer to help in ECE research labs.

What are some helpful text books for this topic?

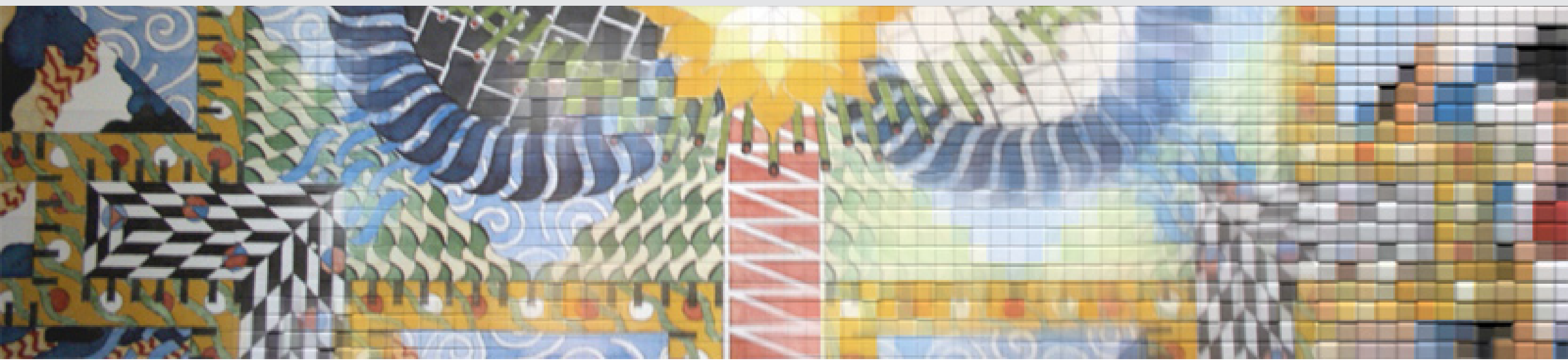
• CMOS VLSI Design: A Circuits and Systems Perspective, 3rd (ed.), Harris
• Computer Architecture: A Quantitative Approach, 3rd (ed.), Hennessy & Patterson
• FPGA-Based System Design, Wolf

Specialization Profile: Signals and Systems by Dr. Don Johnson

Introduction - The "Systems" area represents the classic roots of electrical engineering. The discipline began with the telegraph, the first electrical communication system, and soon thereafter came the telephone. At the turn of the century, communication spread from wired systems to wireless ones with the advent of the radio. As these fields evolved, it became clear that the foundation of communication systems rested on understanding signals, what was being sent, and systems, the devices used to manipulate and send signals. At Rice, the signals and systems area is simply called "Systems."

Today, signals and systems still forms the core of electrical engineering, with older communication systems, like the telephone, relying on both analog and digital forms of signals and systems. Acoustic signals are analog, but most cellular telephones today first turn the analog voltage into a digital signal, representing what you say by a bit sequence. Once in this form, sound can be compressed (like MP3), transmitted over the Internet (using VoIP), stored as a file, encrypted for secure communication, and sent over the telephone company's computer network to complete the call. Today's electrical engineer still must understand signals and systems, but in addition, he or she must consider how analog and digital forms interact and appreciate how computers can be best used to fulfill design goals.

To be an electrical engineer in the Systems area requires a solid background in calculus, physics and computer science. The first course in electrical engineering—ELEC 241—describes signal analysis and linear systems in both analog and digital forms, and how these fundamental ideas have produced today's information revolution.



Hot Topics in Research

Digital signal processing: how to use microprocessors to process signals.
Image and video compression: how to efficiently transmit digital images without noticeable degradation
Digital communication: How to make wireless communication systems more flexible and do more than point-to-point calling.

Rice University - **Learn about some of the topics professors at Rice are investigating right now.**

- Digital Signal Processing: Dr. Baraniuk and Dr. Johnson both develop new ways of processing signals, especially in the face of the ever present nemesis: noise.
- Image Compression: Dr. Orchard wants to find new ways of representing images so that compression schemes can exploit them.
- Digital Communication: Aazhang weds computer networking with wireless digital communication to develop efficient, reliable personal communications systems.

What are some good classes? - - ELEC 431 (Digital signal processing), ELEC 430 (Digital communication)

What are some helpful outside areas of study? - - Beyond calculus, linear algebra is the mathematics most needed by electrical engineers. Furthermore, to understand noise requires a strong background in probability and statistics.

What are some ways to get hands on experience? - - Summer research with faculty, summer internships with ECE industrial affiliates, volunteer to help in ECE research labs.

What are some helpful text books for this topic?

- B. P. Lathi, Signal Processing and Linear Systems
- A. Oppenheim and A. Willsky, Signals and Systems, Prentice-Hall, 2000

Specialization Profile: Physical Electronics by Dr. Bill Wilson

Introduction - The Quantum Electronics specialization area is basically applied physics, focusing on the application of physical principles to engineering problems. Areas of application include semiconductors and integrated circuits, photonic devices (laser, fiber optics, detectors, spectroscopy etc.) and nano-devices. Although many students in the Quantum Electronics go on for at least a Masters degree before they enter the work force, there are also ample opportunities, especially in the semiconductor industry for positions with a Bachelors degree.

While much of what we study in the Quantum Electronics area involves physics, it is the additional electrical engineering training which you will receive in the core courses and in courses which you will take in other specialization areas that sets you apart from a physics major. You have the combined skills of knowing and understanding the physics of how devices work, but also have the electrical engineering background to be able to see how these devices can be used in real world electrical systems.

Hot Topics in Research

Nano Shells & Technology - Use of extremely small structure to perform electrical and optical functions.

Terahertz Waves - Useful for the study and extremely fast and extremely small processes. Can also penetrate otherwise opaque materials.

MEMS (Micro Electrical Mechanical Systems- Using IC manufacturing techniques to build very small motors, sensors etc.

Rice University - **Learn about some of the topics professors at Rice are investigating right now.**

- Terahertz Waves – Dr. Daniel Mittleman
- Nano Shells – Dr. Naomi Halas
- Spectroscopic Polution Detection – Dr. Frank Tittel
- Terahertz Processes in Semiconductors – Dr. Junichiro Kono
- Electronic Materials – Dr. Kevin Kelly
- Fiber Optics Communications – Dr. James Young

What are some good classes? - - Elec 462 (Semiconductor Devices), Elec 463 (Lasers and Photonics)

What are some helpful outside areas of study? - - Physics, linear algebra, and statistics

What are some ways to get hands on experience? - - Summer research with faculty, summer internships with ECE industrial affiliates, volunteer to help in ECE research labs.

What are some helpful text books for this topic?

- For semiconductors try *Physics of Semiconductor Devices* by Sze
- For lasers and optics try *Lasers* by Siegman

Book Suggestions

~ Some lighter reads dealing with the topic of electrical engineering. These are good for any electrical engineer!

- The Chip : How Two Americans Invented the Microchip and Launched a Revolution – T.R. Reid
- The Quantum Dot: A journey into the Future of Microelectronics –Richard Turton
- Also try some of these magazines: Issues of the MIT Technology Review, IEEE Spectrum, and IEEE Computer

Do you have more suggestions? e-mail them to sb.rice@ieee.org and we'll add them!