NEWS FROM THE MIT DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Course VI: EECS is Everywhere

FALL 2006: VOL. 8, ISSUE 1

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A new leadership team in EECS began its work on November 1. Besides myself, the new administration includes Professors Duane Boning and Srini Devadas serving as Associate Department Heads, Professor George Verghese as Education Officer, and Ms. Agnes Chow as Administrative Officer. Installing a new administration provides an opportunity to assess the state of the department and the opportunities before it. In this note, I summarize some key points of our recent assessment.

Observing the activities of the department – in the varied interests of our entering students, in the classrooms, in the research labs, in the directions chosen by our graduates – one is struck by the incredible diversity of opportunities that are currently present. To borrow a phrase from my colleague, Professor Patrick Winston, "EECS is everywhere." We see this in our new students, who have broad interests and a strong desire to apply the traditional strengths of electrical engineering and computer science to other domains: life sciences, materials science, applied physics, synthetic chemistry, synthetic biology, and others. We see this in the range of subjects taught by our faculty, 85-100 each term, including special-topic subjects at the cutting edge. We see this in our faculty's research interests; for example, roughly one-third of our faculty members have research agendas that include work in the biological and life sciences. And we see this in the career paths pursued by our alumni and alumnae, who literally are "everywhere" –

"EECS is Everywhere" continued from page 1

making an impact in a full range of disciplines of engineering, science, medicine, law and business.

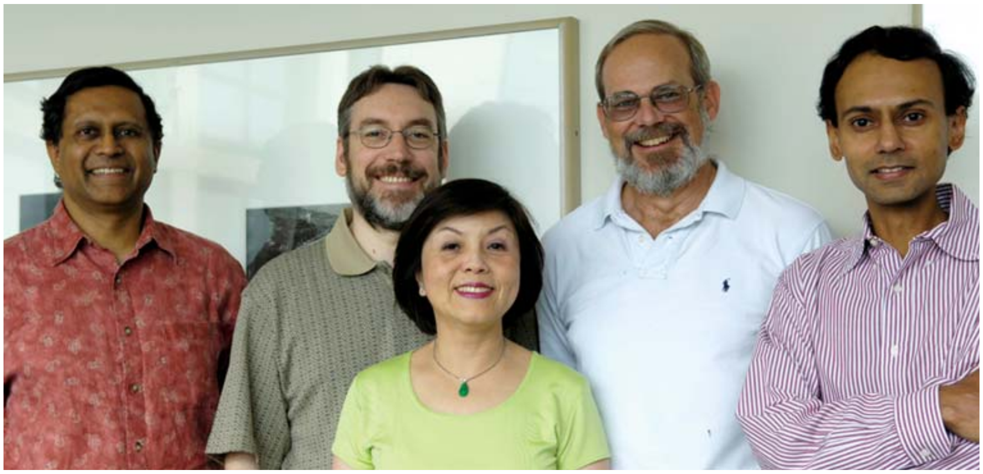
The varied and exciting paths of some of our alumni/alumnae are profiled beginning on page 9 of this newsletter and the ways in which current faculty and department activities are fostering and intersect with diverse disciplines is discussed in more detail.

Our educational philosophy

The dramatically expanding range of research interests of our students and faculty, the rapid proliferation of electrical engineering and computer science technologies in other domains, and the tremendously broad range of career paths that our students pursue are reflected in shifts in our educational philosophy. While we remain committed to providing our students with deep foundational knowledge in EECS, we also believe that transferable skills are equally crucial to the success of our graduates: skills such as problem solving, design, teamwork, and communication that apply equally well to new areas of intellectual endeavor. Thus we have been working to better integrate these elements throughout our curriculum: adding a new senior course devoted to communication skills; adding design elements to many of our fundamental courses; stressing the broad applicability of EECS-style problem solving skills; and modifying existing courses to utilize motivating examples from a range of related disciplines, such as the life sciences.

Revising our curriculum

In a similar vein, the increasing interconnection of domains across the EE/CS boundary, among other factors, has stimulated a major examination of our SB and MEng curricula. A dedicated group of colleagues, led by Professor Tomás Lozano-Pérez, has been engaged for over a year in a far-ranging, detailed, and imaginative design of a new curriculum, described further on page 4 of this newsletter. This is motivated by several themes: providing more flexibility for students to design their degree program; stressing the interactions and interfaces among foundational aspects of EE and CS; encouraging more hands-on experiences; and providing an opportunity for students to explore a selected set of topics in greater depth than in the past. Under the current plan, students will initially take a two-course sequence as an introduction to EECS, where they will engage with major concepts in EECS in an integrated and hands-on fashion, using concrete systems such as a mobile robot and a cell phone as examples and motivations. This will be followed by foundation and then header subjects selected from a range of EECS subdisciplines, and finally new senior-level subjects and a capstone project to develop in depth mastery in areas matching the student's interest. We have already successfully piloted a version of the first introductory course this past spring, and will be piloting a version of the second course this coming fall. We expect to begin the design of the new foundation and header courses, and the rethinking of existing ones, in the coming terms.



EECS leadership from left, George Verghese, Duane Boning, Agnes Chow, Eric Grimson, and Srini Devadas.

Our research portfolio

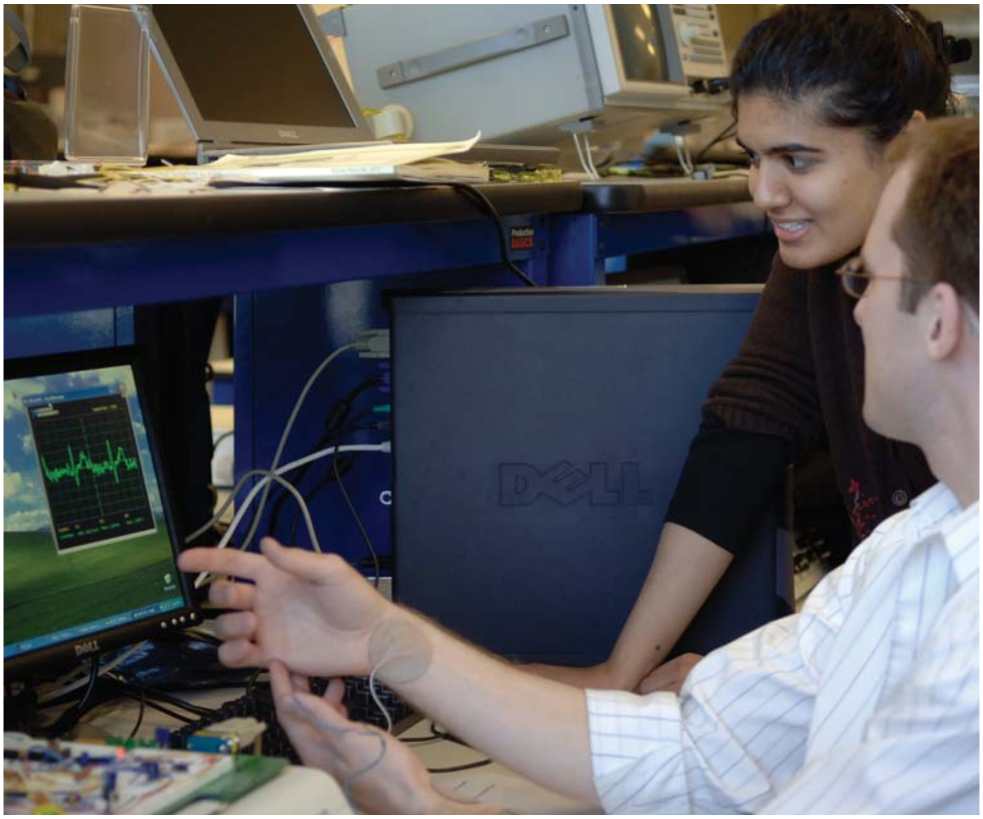
As our research efforts across the department broaden into an array of new related disciplines, we see several themes emerging that demonstrate the notion of "EECS is everywhere." First is the theme of bioEECS – the interaction between the modeling and design techniques of EECS and a wide range of life sciences and biological disciplines. This impressive array of topics is captured at http://www.eecs.mit.edu/bioeecs/ and demonstrates the range of research areas in which EECS methods are influencing research and development in life sciences: from image guided surgical systems, to computational biology, to nanotechnology devices for measuring biological properties, to bioinformatics, to prosthetic devices for hearing and sight and motion, to synthetic chemistry and synthetic biology. Similarly, we see a rapidly emerging set of research topics in nanoEECS – the interplay between extremely small scale measurement and actuation systems and novel material science research: ranging from "lab on a chip" systems for measurement of very small scale biological attributes, to the use of carbon nanotubes for novel device development, to novel power storage systems based on nanoscale elements. And finally, infoEECS: the emerging importance of information theoretic methods in coding, communication, cryptography, security and other methodologies dealing with the manipulation and transmission of information through a variety of media. We see EECS serving as a model for analysis and synthesis of data in fields ranging from the life sciences, to materials science, to applied physics, and to mathematics. You can sample research from affiliated laboratories in the Laboratory Notes section on page 13 of this newsletter.

Globalization of EECS

We believe that it is essential to educate graduates who understand how to succeed in a rapidly evolving global economy. As a consequence, we are exploring ways to integrate globalization into our students' educational experiences. Professor Victor Zue is leading a working group examining best practices by other institutions, and developing a framework within which the department may explore new methods to provide global experiences for our students and faculty.

EECS is everywhere – our outreach

In addition to the role of EECS as a unifying framework for research in a wide range of affiliated disciplines, we also see EECS extending out beyond the department with an array of outreach activities. These include our incredibly successful Women's Technology Program (WTP), and new internship opportunities for our students in a variety of industries. WTP continues to serve as a flagship effort for exposing high school women students to the excitement of EECS. This in-residence, four week summer experience, focused on engaging hands-on experiments and projects, interspersed with lectures in EE, CS and discrete math, provides a wonderful basis for 40 young women each year to experience the excitement of EECS. Targeted at young women who demonstrate an aptitude for math and science, but have expressed reservations or uncertainty about careers in engineering, the program continues to have remarkable success at persuading these talented students to pursue education in engineering. Of the 40 students from the class of 2005, for instance, 30 were admitted to the freshman class at MIT, and 23 of those



Teaching assistant Mark A. Finlayson, SM '01 (foreground) offers suggestions to Pooja Sodha, '07 while she examines his test electrocardiogram on an EKG recorder in 6.121, Bioelectronics Project Laboratory, Spring 2006.

will be attending the Institute this fall. Many of the other students will be pursuing engineering or science degree programs at other top institutions around the country.

We are also excited by the energy of new and continuing student groups. The newsletter highlights, beginning on page 8, the important and valued contributions these groups are making to our academic community.

In closing, I would like to thank our many generous and supportive alumni and alumnae. Part of my activities in recent months has been to meet with many alumni/alumnae to seek their input on the effectiveness of the department in training students well-suited to future success in academia, industry and management. Their input and generous support has been invaluable in helping to provide the highest quality education for our students, shaping the directions of current departmental innovations, and attracting students and faculty of the highest quality, who are the strength of the department. Thanks to our alumni and alumnae, Course VI continues to be the pinnacle to which other departments aspire, and we plan to maintain this standard of excellence into the future.

— W. Eric L. Grimson, August 2006

New Undergraduate Curriculum

EECS Curriculum Innovation Committee

The department is undertaking its first major curriculum revision in a dozen years. A key aim of this revision is to take significant advantage of our joint EECS department. The intersections between EE and CS, as technical disciplines, are deep and varied. One visible point of contact is in computer architecture and digital design; but there are also important contacts between artificial intelligence and estimation and control; between computer networking and information theory and coding; between numerical methods and computational biology; between hearing and speech and natural language; between computer vision and speech and signal processing. Our goal is to have students experience EECS, not just EE and CS. To that end, we will immerse them early in an integrated experience, exposing them to the breadth and richness of the field.

The field of EECS is so broad, however, that no student can be grounded in everything EECS has to offer. Traditionally, we have focused on a small set of "core" topics that all students are required to study. Because there is a huge range of important, elementary material, any particular subset will necessarily omit many fascinating and fundamental topics. Instead, our new approach is to insist that students study a broad set of fundamentals, but not that every student study exactly the same set. We believe that a combination of the integrated introductory experience and early exposure to a broader choice of subjects will help students appreciate the range of possible intellectual and career opportunities in EECS.

While breadth is important, it is also crucial for students to attain mastery in some area. This gives satisfaction and a sense of achievement, as well as the confidence and ability to go on to master new areas. In this curriculum, we will ask undergraduates to choose two specialization areas to study in depth, and to build a curriculum of foundational subjects that support study in those areas. This experience will serve well students who do not continue on for the Masters degree; and it will provide a depth of knowledge that will enhance and deepen the MEng experience for those who do.

EECS Sophomores Ben Gleitzman, Ricky Ramirez and Bill Magnuson as they make final adjustments to enable their robot in 6.099 to turn and drive toward a light, and then play the Hallelujah chorus when it gets close enough, Spring term 2006.

The current proposed SB requirements can be described in terms of a 4-level classification of subjects:

> The Introductory subjects are fully integrated introductions to EECS that introduce the big ideas of EECS in an applied context. All students will take the same two introductory subjects. In addition students are required to take two Mathematics subjects beyond the Institute-required calculus subjects.

> The Foundation subjects are intended to lay the technical foundations for study in EECS. Students will select three of these subjects from a list that currently includes: Circuits and Electronics, Signals and Systems, Computation Structures, Software Design, Analysis and Design of Algorithms.

> The Concentration subjects begin an in-depth exploration of the major areas of EECS. Students will select three subjects from a list that currently includes seven subjects; initially this list is very similar to our existing Header subjects. In addition, the students must select one laboratory subject from a list that includes approximately 10 subjects.

> Advanced subjects are undergraduate subjects that build on the concentration subjects and go deeper into some area. Students will take two advanced subjects. One of our key objectives is to ensure that students explore some of the concentrations in depth.

The intent is that each level of subject has, in general, prerequisites from the previous level, with the introductory level having prerequisites in the general Institute requirements. Our expectation is that this new curriculum will balance breadth and depth, give students a range of foundational knowledge, and provide mastery in some subareas of EECS.

— Members of the EECS Curriculum Innovation Committee, Tomás Lozano-Pérez, chairman

Department News

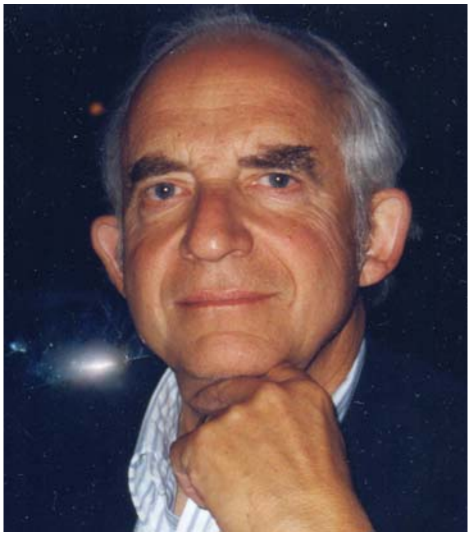
Remembering Al Drake, 1935-2005

Alvin W. Drake, professor emeritus of electrical engineering and computer science, best known and respected as an engaging teacher and fellow faculty member and an innovative thinker and researcher, died Oct. 30, 2005.

Ethernet inventor Robert Metcalfe '68, who was a student of Drake's, called him the "epitome of the MIT professor." "As an MIT undergraduate, I was fortunate to take my first course in probability from Professor Al Drake circa 1966. His enthusiasm for the subject and his ways of teaching got me hooked." Metcalfe was one of many who wrote about memories of associations with Al Drake.

Professor Robert Gallager, a member of the Laboratory for Information and Decision Systems at MIT, said about his LIDS colleague, "Al Drake was in many ways the soul of [LIDS]. In a laboratory noted for brilliance, even within MIT, Al was a voice for wisdom, humanity, and not taking ourselves too seriously… Inside and outside LIDS, he was a friend and mentor to legions of both strong and less strong graduate students. He helped them leave here with wisdom and confidence… He kept teaching those of us on the faculty that our impact on students is more important than the new papers we are publishing."

A celebration of Al Drake's life was held at the MIT Chapel on December 3, 2005. Drake is survived by his wife Julie Atwood, his brother Jerome, stepson Todd C. Wheeldon and Todd's wife Babette, and his grandsons Drake and Fenix.



Other Department News

As part of the Department's ongoing efforts to develop valuable educational ties with industry, a new Industry Programs Office (IPO) has been established in EECS. **Joel Schindall**, the Bernard Gordon Professor of the Practice in EECS, has accepted the position as Director of the IPO.

Working with Joel Schindall within the umbrella of the Industry Programs Office, **Marcus Zahn** continues to direct the VI-A Cooperative Program, **Cynthia Skier** directs the Industrial Connection Program and **Charles Sodini** is helping to facilitate the new international component of VI-A.

Freshmen enjoy an EECS preview day, Spring 2006.

Prof. George Verghese joins his colleagues in welcoming the new graduate student 'admits' for the Open House in March, 2006.

Anantha Chandrakasan, the Joseph F. and Nancy P. Keithley Professor of Electrical Engineering and, since 2003, Associate Director of the Microsystems Technology Laboratories (MTL) has been appointed the new Director of MTL effective Sept. 1, 2006 as announced by School of Engineering Dean **Thomas L. Magnanti**.

Magnanti cited the outstanding leadership work accomplished over the seven year tenure of outgoing MTL Director **Martin Schmidt**. EECS Department Head **Eric Grimson** joined Magnanti in expressing appreciation to Schmidt and stated "I know Anatha will excel at this job, and I look forward to working with Anantha in his new role."

W. Eric L. Grimson, Department Head
Duane S. Boning, Associate Department Head
Srini Devadas, Associate Department Head

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Awards and Honors 2006

FACULTY

Faculty Promotions

Full Professor

Hari Balakrishnan — networks, sensor systems, and distributed systems

Denny Freeman — biomedical engineering, measurements of nanomotions, auditory system

Alex (Sasha) Megretski — nonlinear systems, control, optimization

Martin Rinard — program analysis, compilers

Daniela Rus — robotics, sensor nets, mobile computing

Associate with Tenure

Robert Morris — wireless networked computer systems, secure operating systems

Rahul Sarpeshkar — low-power signal processing and systems, biomedical and bioelectronic systems

Associate without Tenure

Marc Baldo — organic transistors, electrical properties of organic materials

Fredo Durand — graphical rendering, computational photography

Jongyoon (Jay) Han — nanofabrication, nanofluidics, biomolecules

Steve Massaquoi — sensorimotor models, neuromorphic engineering

Rob Miller — useable security, useable program automation, human-computer interfaces

Mike Perrott — high speed communications systems, phase locked loops, CAD

Jovan Popovic — animation, shape modeling, human motion analysis

Joel Voldman — cellular bioMEMS, bioengineering

Lizhong Zheng — wireless communications, information theory

Chair Appointments

KDD Career Development Chair:
Lizhong Zheng

Class of 43 Career Development Chair:
Asu Ozdaglar

NBX Career Development Chair:
Dina Katabi

Ross Career Development Chair:
Regina Barzilay

Awards and Prizes

SIAG/CST Prize:
Pablo Parrilo

TR 35:
Regina Barzilay, Samuel Madden

Dantzig Dissertation Award:
Devavrat Shah

National Institute of Medicine:
Peter Szolovits

ACM UIST 2005 best paper:
Robert Miller

IEEE Fellow:
Jesus del Alamo

Fellow, Optical Society of America:
Qing Hu

National Academy of Engineering membership:
Dimitri Antoniadis, Frans Kaashoek

Van Wijngaarden prize:
Nancy Lynch

IEEE SPS Educator's Award:
Al Oppenheim

Sloan Research Fellows:
Erik Demaine, Fredo Durand, Dina Katabi

MIT Excellence Awards:
Anne Hunter, Marilyn Pierce

IEEE 2006 Bell Award:
John M. Wozencraft

2006 MacVicar Fellowship:
Denny Freeman

Pender Award:
Mildred Dresselhaus

Honorary Doctorate, ETH:
Barbara Liskov

Microsoft Faculty Fellow:
Regina Barzilay

Australian Academy of Science-corresponding member:
Rodney Brooks

National Academy of Science membership:
James Fujimoto

Fellow of AIMBE:
Sangeeta Bhatia

Irving M. London Teaching Award:
Collin Stultz

OSA 2006 Frederic Ives Medal:
Erich P. Ippen

Departmental Special Recognition Awards

For outstanding service to EECS:
Robert T. Morris, Dorothy Curtis, Joel Voldman, Agnes Chow

Jerome Saltzer Award:
Joel I. Dawson

HKN Underground Guide Best Teaching Award:
Steven Leeb

MIT ACM IEEE Best Academic Advisor Award:
George C. Verghese

Graduate Student Association – Counselor Award:
Alan V. Oppenheim

Ruth and Joel Spira Award for Distinguished Teaching:
Valdimir Bulovic

Richard J. Caloggero Award:
Amanda Cheng and Claire Benoit

STUDENTS

Undergraduate Students

David A. Chanen Writing Award—for an outstanding paper in 6.033:
Tamara Stern '06

Robert M. Fano UROP Award—for the best EECS UROP project:
Surasak Chunsrivirot '06

Licklider UROP Prize:
David Moore-Pitman '06

George C. Newton Undergraduate Laboratory Prize in fall, 2005 6.111:
David W. Rush '07,
Christopher A. Wilkins '06

Northern Telecom/BNR Project Award—for an outstanding 6.111 laboratory project - spring term 2006:
Ravi Palakodety '07, Vijay Shah '06,
Shi Ling Seow '06, Yun Wu '06

New Faculty Profile

Nylander Undergraduate Advanced Project Award:
Kevin G. Der '06
Anna Pogosynats UROP Award—for an outstanding computer science UROP project:
Beckett W. Stemer, math

Graduate Students

Carlton E. Tucker Teaching Award:
Anthony Accardi
Charles and Jennifer Johnson Thesis Prize—for an outstanding MEng thesis in computer science:
Michael F. Lin, Philip J. Guo
Harold L. Hazen Teaching Award:
Adam A. Kumpf
Frederick C. Hennie III Teaching Award:
Ola Ayaso; Asfandyar Qureshi
David Adler Memorial Thesis Prize—for outstanding Masters thesis in electrical engineering:
Michael S. Bradley; Christopher J. Emig
Morris Joseph Levin Award—for Masterworks Oral Thesis presentation:
Thomas A. Baran
Ernst A. Guillemin Thesis Award—for outstanding master's thesis in electrical engineering:
Lav Varshney
William A. Martin Memorial Thesis Prize—for an outstanding master's thesis in computer science:
Matthew D. Rasmussen
George M. Sprowls Award—for an outstanding PhD thesis in computer science:
David G. Anderson '05; Nissanka B. Priyantha '05
George M. Sprowls Honorable Mention:
Emin Martinian '05; Simson Garfinkle '05
Raymie Stata Award for Outstanding Teaching:
Hubert Pham; Justin M. Paluska; Saikat Gu

Tomás Palacios joins the EECS Department of MIT in September of 2006 as an Assistant Professor and a member of the Microsystems Technology Laboratories. He earned a degree in telecommunications engineering from the Polytechnic University of Madrid in 2001, and his MS and PhD degrees in Electrical Engineering from the University of California – Santa Barbara (UCSB) in 2004 and 2006, respectively.

He has been working on novel semiconductor devices since 1998, when he joined the Institute for Systems based on Optoelectronics and Microtechnology, in Spain. In 2000, Palacios studied new Si devices for radiation-hard electronics with the Microelectronics Group of the European Organization for Nuclear Research (CERN, Geneva). In 2002, he joined Prof. Mishra´s group at UCSB to develop nitride transistors for mm-wave applications, establishing the state of the art in power amplification at these frequencies.

Palacios´ research interests include the design, processing and characterization of new nitride transistors for applications beyond 100 GHz. He is also working on new concepts for biosensors and bioactuators as well as on the use of the unique properties of nitrides and nanotechnology for power generation and conversion. In his spare time, Tomás enjoys reading, listening to classical music, hiking and attending plays.

Eric Grimson joined the 2006 EECS graduates celebrating at the Hooding reception, June 2006.

EECS Student Groups

GSA leadership team with EECS special recognition award, June 2006

GW6 Open House 2006

HKN Expo 2006 presenter Matt Welsh demonstrating his voice over IP phone system, designed and implemented as a final project for 6.111, Digital Systems lab class. Prof. Charles Sodini, second from left, joined the large group of interested guests.

THE GSA

While many graduate students are focusing on individual endeavors, the members of the EECS Graduate Student Association (GSA) are working to make the EECS graduate program better for all of its students.

This enthusiastic group, committed to fostering communication and promoting academic, professional, and social development within EECS, works to build community by organizing new initiatives like an orientation program, TA workshops, and TQE info sessions, and expanding upon existing activities like the EECS open houses.

During the GSA orientation program, current students welcome new students to the Department and inform them about life within EECS. Through its welcome dinner, information sessions, Prudential skywalk event, and recreational day at Endicott House, the GSA orientation program helps new students become acquainted with current students, professors, one another and the Department. The casual welcome dinner provides a venue for new students to informally ask questions when they first arrive, while the information sessions allow current students to share insights and information that they wish they had known when they started the program. The Prudential skywalk and recreational day provide additional opportunities to socialize with other students and faculty members so that the new students begin to feel like a part of the EECS community before the semester begins.

Through endeavors like these, GSA members from all parts of the EECS community work together to make the departmental environment more dynamic and enjoyable while adding to their own quality of life at MIT in EECS as well.

GW6

The Graduate Women in Course 6 (GW6) has a mission to facilitate interaction and bonding between graduate women in EECS, help address the needs of the department as pertaining to women students, and organize outreach events for the community at large. The group started four years ago with the goal of creating a support network for female graduate students. This goal was accomplished through social gatherings in an informal environment, which fostered discussions about issues at hand. Currently, the group is expanding its programming to encompass broader needs of the Department as a whole.

One of the events scheduled for this coming year is “Family in Academia,” which will be sponsored jointly by the EECS Graduate Student Association (EECS-GSA). In this event, we hope to have a panel of both male and female professors and spouses to discuss the issues that arise while on the strenuous tenure track in academia.

Last year, GW6 was one of the groups at MIT that helped organize the MIT Graduate Student Volunteer Day. We plan to continue our participation in this event during the coming year. In addition to these outreach events, we will also continue to hold social dinners to cultivate networking among graduate women in EECS.

HKN

Greetings from the Beta Theta Chapter of Eta Kappa Nu! As the national honor society for Electrical Engineering and Computer Science, our purpose at MIT is to enhance the EECS community through academic and social endeavors.

A successful new member initiation and elections in April left us with a set of fresh officers ready to take charge for the upcoming year. We would like to thank Brian Myhre, Calvin On, Liang Hong, Jennifer Novosad, and Lynne Salameh for their guidance and leadership in the past year and facilitating a smooth transition. Some of the events from last year include:

EECS Grads are Everywhere

The first annual General Body Meeting of the HKN Beta Theta Chapter was held in December at the Faculty Club. The meeting was a great opportunity for members from different phases and paths of life to interact with each other, as well as an impetus for members to get more involved in the organization. Thanks to Professor Patrick Winston for a great keynote speech, Qualcomm for their generous sponsorship, and to Lynne Salameh '06 for organizing the event.

The HKN Student Project Expo, held during IAP in January 2006, was an informal event where undergraduates and MEng students were invited to present projects from their research, class work and co-curricular interests. With significant student, faculty, and corporate participation, it is definitely an event we will continue to develop next year. Kudos to our IAP Chair Maxine Lee '06 for an awesome job!

Daniel Leeds further developed the tutoring program for undergraduates by hosting regular social events for the tutors and the tutees and continued this steady and very strong aspect of HKN's efforts.

The Course 6 Underground Guide is one of our longest running services to the department. Published semi-annually, this review of all the classes offered in Course 6 continues to serve as a great channel for feedback to the teaching staff and a resource for future students. This year we are transitioning to a fully online review system, thanks to the enormous efforts of our Underground Guide chairs, Brian Wu and Daniel Shultz, and a successful pilot they ran in Spring 2006.

"I can't think of a day in the twenty-five years since I graduated when I haven't called upon the fundamental skills I learned in EECS at MIT. It was an excellent education and one that prepared me well for the career I have today,"

Armen Avanessians took what seemed a typical path after earning his undergraduate degree from EECS in 1981: he gained a Masters degree in electrical engineering (Columbia University) and began his working life designing circuits at Bell Labs. In 1985, however, his career took a different turn when he was invited to join a four-person Strategies group in the currency and commodities division of Goldman Sachs.

Today, as a Managing Director of fixed income, currency & commodities strategies, equity strategies, and investment banking strategies at Goldman Sachs, Avanessians describes the Strategist role as "the quantitative and technical heart of Goldman's businesses." He notes: "Although finance and electrical engineering are different fields, they both require well-developed quantitative and problem-solving abilities."

Indeed, a current undergraduate student in EECS at MIT will gain a deep education in engineering skills and principles—supported by fundamentals in the sciences and humanities, as well as communication skills. But that is not all. In addition to opportunities for course study in such diverse areas as synthetic biology, computational photography, power electronics, data communication networks, design and fabrication of MEMS, and cognitive robotics, students obtain hands-on, real-world experience through participation in specially developed activities that combine with a variety of EECS courses.

For example, Professors Daniela Rus and Seth Teller are currently retargeting their existing undergraduate subject, 6.142, Robotics: Science and Systems II, to focus on the DARPA Urban Grand Challenge. The ambitious goal is to develop an autonomous passenger vehicle, capable of driving itself safely through an urban environment amidst other moving vehicles. This will involve intermediate capability tests of increasing difficulty over 18 months, culminating in the actual competition in November 2007.

Professors Rus and Teller plan to offer a graduate companion subject, and form teams of undergraduates and graduate students to focus on various sub-problems of the challenge, including perception, control and planning, providing a very real-world experience.

With exposure in such a learning environment, it is not surprising that EECS graduates pursue their passion in careers that do not necessarily follow the typical pattern, and in a variety of careers spanning the financial, management, legal, engineering, medical and service sectors.

Larry DeMar, SB '79, has always had a fascination with games. While majoring in 6-3 at MIT, DeMar was often found at the Student Center game room. After seeing DeMar's 6.112 project (an arcade style video game developed with long time friend Curt Sanford '80), Prof. Alvin Drake challenged DeMar to design a lecture demonstration system for his 6.041 probability class. DeMar built a

computer video system and wrote the software for this project (winning the Guillemin prize in 1980 for Best Undergraduate Thesis in Electrical Engineering).

"I was in the middle of the emergence of this [personal computer] industry while the technology that would propel it was just coming into existence. I played a great deal of Space Invaders and the computerized pinball machines that had just been introduced—while learning about the technologies that made these games tick."

Following MIT, DeMar became a skilled game designer and system developer for pinball maker Williams Electronics (in Chicago) working with legendary designer Eugene Jarvis, with whom DeMar independently formed video game development group Vid Kidz. Ultimately, DeMar, now the holder of 26 US patents in the fields of amusements games, bowling systems and slot machines, branched out to start Leading Edge Design in 1999, a company devoted to creating patent-protected casino game concepts.

"'Collect the data; analyze the patterns; take educated risks.' This has been my modus operandi since my days at MIT and the motivation for starting Unica Corporation," states **Yuchun Lee**, BS and MS, '89. Studying data mining at EECS, Lee relates that he "learned from the best and was most inspired by his thesis advisor, Richard Lippman" (at MIT Lincoln Laboratories), with whom he later joined to co-author the book "Solving Data Mining Problems Through Pattern Recognition."

Although Lee calls it a "foray," he points to his participation in the "infamous MIT blackjack team as an opportunity to apply statistics and probability to the game"—something that is uniquely possible at a place like MIT. Lee teamed with EECS classmates, David Cheung and Ruby Kennedy to co-found Unica in 1992. Lee notes: "The practice of

calculating risks and seizing opportunities became the mantra for starting [our] company and innovating technology. MIT's strong culture of entrepreneurship fostered every element of innovation."

In addition to the entrepreneurial possibilities arising in EECS, students are able to participate in leading edge research in many areas. Examples include Professor Isaac Chuang's application of the physics of NMR interactions to create ion trap-based computational devices for quantum computing and Professor Saman Amarasinghe's development of programmable microfluidic chips that in combination with high-level software libraries enable large, complex biological experiments to be executed on a single platform. *[See other examples of "EECS is everywhere—Projects" in the sidebar on page 11].*

No matter the area, students repeatedly find excitement and discover themselves as they become involved in research groups such as these. **Sramana Mitra**, SM '85, is a good example.

"The intellectual joy of solving difficult technical problems that had real-world applications, or solving real-world problems with creative use of technology turned out to be where my sweet-spot was. MIT's gift to me has been building the confidence in my ability to figure things out."

Following an undergraduate degree from Smith College in computer science and economics, Mitra became an EECS graduate student in the mid-nineties under Prof. Anant Agarwal working intensively with a group on a parallel computer called Alewife. It was fortuitous that Agarwal was extremely busy working on his own startup. Mitra not only had a mentor who gave her real world exposure to the start up process, but as she puts it, "The environment nurtured a certain confidence in people's ability to figure things out." Two years later, she started her own company and has since started two more. Mitra now continues in Silicon Valley as a strategy consultant with experience spanning hard core technology disciplines like semiconductors to sophisticated consumer marketing industries including fashion and education.

An avid writer who maintains a thoughtful set of writings on her blog, Mitra reflects: "Did I know all this when I started my journey? Surely not. But for sure, my MIT education

steered me in this direction in the early years. Today, it has become second nature. It is hard to even look back and see when and where I made certain turns. All I can say is that I value what MIT brought to my life tremendously."

Despite the burst of the 1990s bubble, entrepreneurship continues as a way of life at MIT—particularly in EECS, where roughly 10% of EECS students start out in the risky, exciting world of start-ups. Within the past few years start-ups by EECS grads span the gamut from airline reservation software to biotech prenatal genetic testing.

Eugene Kuznetsov, SB '98, fascinated with the entrepreneurial way of life since his early teens, surrounded himself during his four years at MIT with part-time work during the semester and full-time work the rest of each year. At first, this was for smaller companies, and then eventually at Microsoft. Although he admits that working at start-ups at MIT wasn't the ideal way to be a good student, in his words, "Even a short stint as a programmer at a startup offers an opportunity to learn something about its technical, sales and management strengths and challenges."

Following his MIT undergraduate experience, Kuznetsov worked briefly at Analogic. Here, Bernard Gordon (founder and then

Examples of current "EECS is Everywhere" research projects

> **Solid-state photosynthetic solar cells** — integration of a photosynthetic protein molecular complex with a solid-state electronic device to create an efficient, organically based solar cell (Baldo)

> **Programmable microfluidic chips** — a high-level programming language and software system, BioStream, that enables general-purpose microfluidic chips to automatically carry-out large, complex biology experiments (Amarasinghe)

> **CarTel** — a computing system to collect, process, deliver, and visualize data from mobile sensor networks such as sensor-equipped automobiles http://cartel.csail.mit.edu/ (Balakrishnan, Madden)

> **Nanobiotechnology** — using quantum dots and magnetic nanoparticles to target tumors in vivo (Bhatia)

> **Quantum computers** — using the physics of single atoms and molecules to create computational systems based on quantum mechanics (Chuang)

> **Computational photography** — using computational methods to enhance digital photographs and video, such as preserving detail while extending the dynamic range of images (Durand)

> **Computational medicine** — computer-assisted diagnosis of cardiac disorders; devices to detect and prevent epileptic seizures (Guttag)

> **Carbon nanotubes** — developing synthesis and control techniques to create electronic devices based on carbon nanotubes (Jing Kong)

> **Game theory** — applied to network routing (Ozdaglar), cryptography (Micali), and computational biology (Jaakkola)

> **Robotics** — flapping-winged robots (Tedrake), and swimming robots (Rus)

> **BioMEMS** — micro and nano-devices for analysis of molecules, particles and cells (Voldman, Han, Freeman)

> **Nano-surgery** — studies of nerve regeneration and degeneration through femtosecond laser nano-surgery and multi-photon imaging (Yanik)

> **Ferrofluids** — for magnetic microfluidic devices, with biomedical applications such as hyperthermia treatment, directed drug delivery, and magnetic resonance imaging contrast that is coupled to cancer therapies (Adalsteinsson, Zahn)

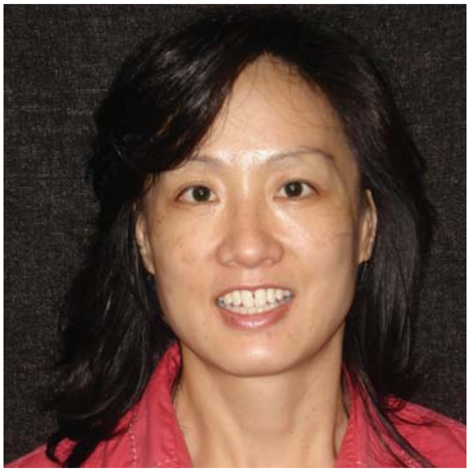
CEO) was another inspiration—an electrical engineer who at 70 was combining both entrepreneurial success and continued technical involvement.

Then in 1999, girded with this experience and "the Course VI spirit," Kuznetsov (and several other Course VI alums) started DataPower, most noted for integrating XML-aware hardware into the security management infrastructure at existing Global 1000 enterprise infrastructures. DataPower was acquired by IBM in late 2005. Kuznetsov, as DataPower founder and CTO, was selected in 2005 as one of InfoWorld's Top 25 CTOs.

Kuznetsov recaps his experience stating: "Course VI provided both the confidence to attempt a whole new way of connecting computer systems and the engineering knowledge to actually make it work. But it's also the culture — IBM has this great term, "innovation that matters" — which is about doing groundbreaking research that has a positive impact on the world. And MIT engineering is like that: really deep, but with an eye to the wider world."

In an interesting twist of career development midst the burgeoning 1990s, **Michelle K. Lee**, SB and SM '89, came to appreciate a different side of the growing world of computer technology. Head of Patents and Patent Strategy at Google since 2003, Lee states:

"I certainly did not attend MIT with the idea of becoming an intellectual property lawyer. However, during my time at MIT, the famous Apple v. Microsoft copyright infringement case involving graphical user interfaces was being litigated, and it dawned upon me that there were and would continue to be some very interesting, cutting edge, unanswered issues in intellectual property law involving computer technology. I thought, with my MIT Course VI background, I could make a valuable contribution in this area. To further confirm my interest in intellectual property law, I took Robert Rhine's class on innovation and patent law."



As an MIT undergraduate, Lee ended up in Course VI-1 (EE) because she enjoyed calculus and physics. "I loved learning about Maxwell's equations in 6.013 and 6.014. Those equations are so elegant!" It was completely natural for her to follow up with a Masters in computer science since she was part of the VI-A program with Hewlett Packard Research Labs. Lee went on to complete her law degree at Stanford in 1992. It was only a matter of time and experience working as a top flight IP counsel in Silicon Valley, before Google recognized her legal passion for innovation and engineering.

In a few cases, a graduate from EECS at MIT may follow a totally unpredicted course, nevertheless finding good use for his/her education along the way. Upon graduating with his SM and EE degrees in 1986 (under Professor Peter Szolovits), **Robert Kunstaetter**, who had earned a medical degree from McGill University prior to MIT, decided to take part with his wife Daisy in the National Outdoor Leadership School (NOLS) in Lander, Wyoming. This opened the door for the Kunstaetters' extensive explorations throughout Central and South America (additionally connecting with Daisy's parents in Ecuador). Following a re-supply mission in 1988 with the Chilean Navy to bases in Antarctica, they returned in 1994-95 to work for Adventure Network International, the first company to offer tours to the Antarctic mainland. The Kunstaetters' experiences have culminated in numerous trekking and travel guidebooks. Robert Kunstaetter shares his thoughts:

"Although we never followed traditional career paths, our educations have left a lasting impact on us. My computer science background, for example, has been an asset when developing digital trekking maps or an intelligent Geographic Information System to store material for our guidebooks.

Much more important though, the principles we learned have continued to help guide our way forward. In retrospect, we have had a great many satisfactions and very few regrets. We therefore encourage other MIT EECS graduates to dare to be different, to regard their education as a means of broadening rather than narrowing their horizons."

Laboratory Notes

Machine Learning Control of Underactuated Mechanical Systems

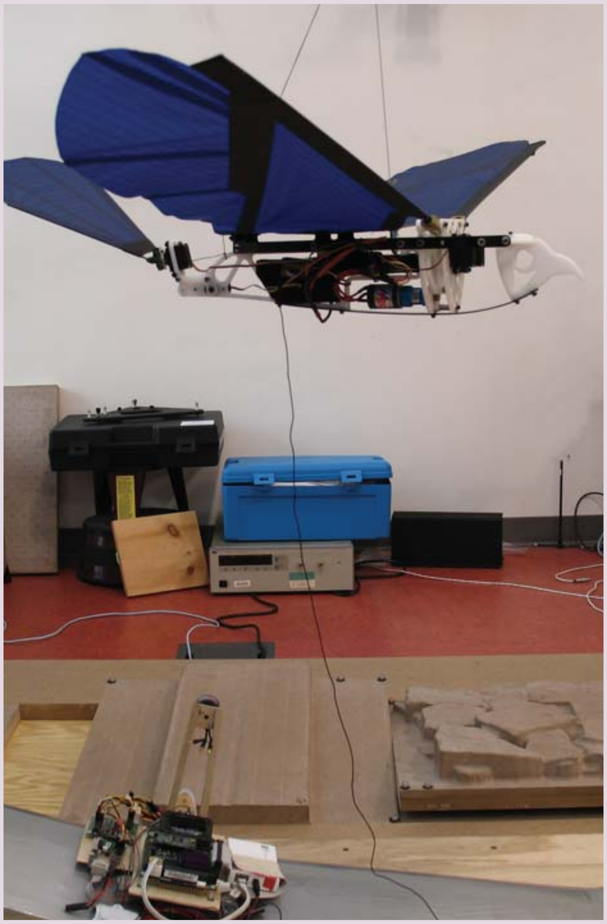
Russ Tedrake

Computer Science and Artificial Intelligence Laboratory

Robots today move far too conservatively, using control systems that rely on maintaining full control authority at all times. Humans and animals achieve far superior performance by routinely executing motions that involve a loss of instantaneous control authority. Solutions in the literature for this "underactuated" control problem are few and problem-specific.

Recent advances in machine learning for control have made it possible to consider a more general solution to the underactuated control problem based on approximation techniques. In the Robot Locomotion Group, we are extending these techniques to develop a breed of simple mechanical systems designed to achieve extraordinary dynamic performance. Pictured right is a biped with a single motor at the hip which, using a nearly optimal control system, will walk over a surprising amount of terrain. The robotic bird, pictured below, left, uses flexible flapping wings to trade off the efficiency of an airplane with the maneuverability of a helicopter. This bird, which is already flying around Killian court, will be able to catch (bright orange) bread-crumbs out of the air and land on a perch.

A key feature of our robots is that we spend a considerable amount of time on mechanical design. Our walking robots are capable of walking stably down a small ramp without any actuators, and our birds glide passively before they learn to fly. These mechanical design elements have a dramatic effect on the performance of the learning control system, and ultimately govern the dynamic capabilities of the robots.



Keyword Commands for Application Scripting

Rob Miller

Computer Science and Artificial Intelligence Laboratory

Many modern applications have scripting languages that allow users to automate tasks within the application. Microsoft Word, for example, includes a variant of Basic. For many users, however, the learning curve for writing scripts is prohibitively steep. One of the biggest hurdles is learning the syntax of the language and using it correctly.

Rob Miller and Greg Little (a PhD student in EECS) are developing a new approach that avoids syntax, and focuses instead on the presence of keywords in an expression called a keyword command. Consider the *keyword command left margin 2 inches* in Microsoft Word. A prototype system can translate this command automatically into Visual Basic, producing *ActiveDocument. PageSetup. LeftMargin = InchesToPoints(2)*.

With keyword commands, the user need not worry about strict requirements for punctuation and grammar, and they can be more verbose (*set the left margin to 2 inches*) or use a different order (*2 inches, margin left*). In addition, the user does not have to search through documentation to learn the exact name for the LeftMargin property or learn how to access it. A keyword command is in fact a search over the application's programming interface, but this search produces executable code.

Two keyword command prototypes have been implemented so far: one for Microsoft Word, which translates keyword commands into Visual Basic code, and the other for the Mozilla Firefox web browser, which translates keyword commands into scripts that automatically navigate web pages and interact with web forms. A user study of the web browser prototype found that even with no training, users were able to generate successful keyword commands for 90% of typical web browsing tasks, and that their first attempted keyword command succeeded 73% of the time. Work is underway on a prototype for the Java API.

"Lab Notes" continued from page 13

Nano-enhanced Thermophotovoltaics

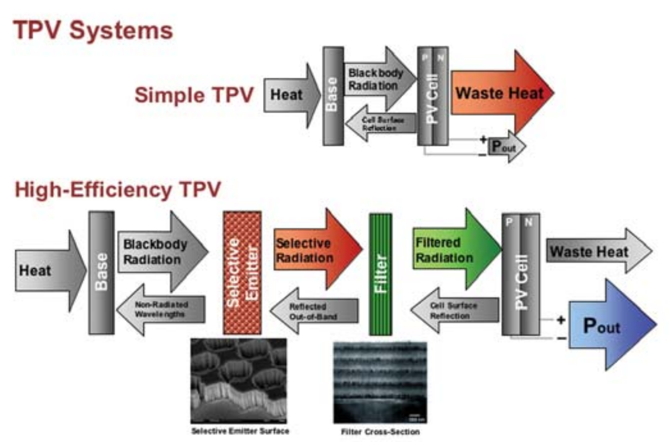
John G. Kassakian

Laboratory for Electromagnetic and Electronic Systems

The Laboratory for Electromagnetic and Electronic Systems is exploring several exciting areas in which nano-sculpting of materials can provide dramatic improvements to "discarded" technologies for electricity generation and storage — perhaps to the point that they surpass the effectiveness and efficiency of more modern devices.

Using nanotube-enhanced electrodes to make a non-chemical battery has already been reported in an earlier Newsletter. Another project relates to the use of photovoltaic (PV) diodes to convert heat directly into energy. Thermophotovoltaic (TPV) power conversion, first conceptualized in late 1950's, would seem to be particularly appealing because of its static nature, which makes TPV systems amenable to compact designs, long-lifetime, and quiet, low-maintenance operation. However, TPV systems are notoriously inefficient, and therefore rarely used, because only a limited portion of the radiant energy is of the proper wavelength to be absorbed by the PV diode.

Today, we are able to use nanotechnology to increase TPV efficiency by engineering and producing selective emitter surfaces and filters. The doctoral research of Ivan Celanovic and Natalija Jovanovic investigates the fabrication, modeling, characterization, and application of micro-fabricated two-dimensional (2D) photonic crystals (PhCs) as selective emitters and means of achieving higher efficiencies in combustion-driven TPV systems. Our simulations and first-sample measurements are in good agreement, and open the door to significantly increasing efficiency and lowering the cost of TPV systems in the future.



Optimization Methods for Analysis and design

Pablo A. Parrilo

Laboratory for Information and Decision Systems

The conventional techniques for design of control and communications systems have been mostly based on human creativity, intuition, and incremental improvements. In recent years, however, there has been a strong trend towards the use of formal and automated tools. In particular, in many areas of control and communications, as well as electrical and mechanical design, the ideas and methods of mathematical optimization theory have revolutionized the state of the art.

Indeed, to be able to carry analysis, design, resource allocation, and optimization tasks on large scale or high-performance engineered systems, the use of formal techniques based on well-defined system descriptions is unavoidable. For many current and future man-made systems, the sheer size, complexity, performance and robustness requirements are formidable, and simply cannot be easily guaranteed or estimated, requiring instead intensive computational and simulation-based methods.

Prof. Parrilo's research addresses the development of efficient methods for the analysis and design of engineering systems, often requiring the integration and extension of techniques from different domains. These efforts include the development of a theoretical framework that unifies algebraic tools and convex optimization, and applications to dynamical systems and game theory.

A challenging project currently under investigation is the specification, design and verification of distributed dynamical systems (e.g., teams of autonomous vehicles collaborating towards some higher-level task in an uncertain environment), and the complications that communication constraints impose on their performance. These complex problems often require a combination of ideas from continuous optimization, optimal control, information theory, dynamic games, model checking, and distributed systems.

Besides their intended direct application, an important side effect of the development of fundamental computational methodologies is their practical relevance in a variety of scientific and technological contexts. In collaboration with domain experts, some of the techniques developed by Prof. Parrilo have been successfully applied in areas as diverse as quantum information theory and biochemical system modeling.

Breaking the Analog Circuit Bottleneck

Hae-Seung Lee

Microsystems Technology Laboratories

Digital circuits have enjoyed an exponential increase in performance during the past several decades from CMOS technology scaling. However, since most real world signals are analog, analog circuits are an essential part of most electronic systems. They are used to amplify, process, and filter analog signals, and to convert analog signals to digital signals and vice versa. Unfortunately, analog circuits have not benefited in similar fashion from technology scaling. On the contrary, the technology scaling has had a predominantly negative impact on analog circuits.

Traditionally, many analog circuits in mixed-signal environments have relied upon operational amplifier based sampled-data signal

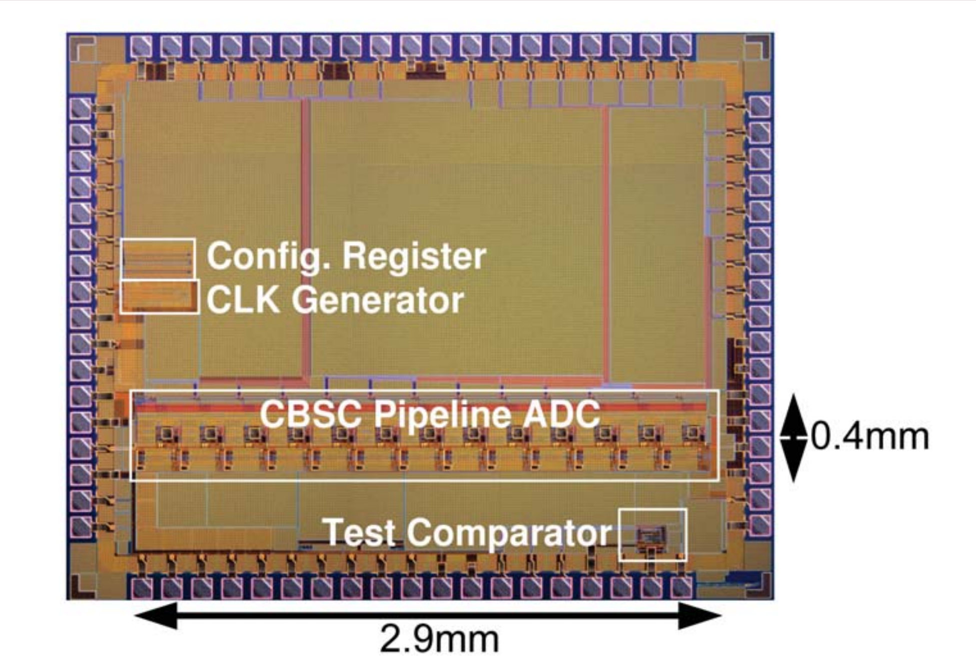


Fig. 1. Microphotograph of prototype analog-to-digital converter in CBSC technology

processing. Two adverse side effects of technology scaling that have a significant negative impact on analog circuit design are the reduced signal swing and the decrease in intrinsic device gain. Gain is important in feedback-based, analog signal processing systems because it determines the accuracy of the output value. Cascoded amplifier stages have been a popular solution to increase amplifier gain, but they further reduce the signal swings of scaled technologies. In addition, the applicability of Op Amp based circuits is unclear in non-Si technologies such as compound semiconductors, carbon nanotube/nanowire devices, and molecular devices.

Prof. Lee's research group recently demonstrated a new class of analog circuits called comparator based switched capacitor (CBSC) circuits (Fig. 1) that promises to eliminate the bottleneck caused by Op Amps. The CBSC technique is based on the observation that an accurate output voltage is necessary only at the sampling instant by the next sampling circuit. In conventional sampled data circuits, an operational amplifier drives its inverting input to virtual ground. In a CBSC, a comparator detects the instant the input crosses virtual ground. The comparator output is used to determine the sampling instant. Since the comparator only detects the virtual ground crossing rather than driving as an Op Amp does, it is much more power efficient. Analyses indicate that CBSC's have a potential for 2 orders of magnitude lower power at the same performance level. In addition, CBSC may enable high performance analog circuits in non-Si technologies because complementary devices are not needed in comparators. The CBSC technique has a wide range of applications, including pipeline and delta-sigma A/D converters, D/A converters, discrete-time amplifiers, filters, as well as sensor and actuator interface circuits.

Modern Interfaces – Circuit Design, Communication Theory and Convex Optimization

Vladimir Stojanovic

Research Laboratory of Electronics

From game consoles and PCs, to network routers and supercomputers, chip-to-chip communication has emerged as a serious performance bottleneck. Due to the bandwidth limitation of wires, these interfaces have recently grown into full communication micro-systems. In these power constrained systems, maximizing the data rate well into multi-Gb/s range is a complex multi-dimensional optimization problem. In the Integrated Systems Group, we are attacking this problem by cutting vertically through the system design hierarchy.

By adding coding, we intend to improve both link robustness and energy-efficiency. Unlike in standard communication systems, we investigate design of codes with high energy efficiency and gain with atypical noise sources like jitter, reflections and crosstalk. To do this, we are developing a unique stochastic high-speed link simulator that is able to work with correlated data and characterize the impact of coding down to required bit-error-rates of 10^{-15} (impossible to achieve with standard Monte-Carlo behavioral simulation).

We are also developing a link architecture that unifies the equalization and clock-and-data recovery (signal processing and synchronization) sub-systems into one higher-performance and more energy-efficient front-end. This link design is made possible by taking advantage of the complex interplay of fractional equalization techniques, innovative adaptive algorithms and high-rate, energy-efficient mixed-signal circuits.

With high-speed links as inspiration, we are working on formulating this complex interplay among different blocks and levels of hierarchy and capturing the interface system design problem as a hierarchical convex optimization (resource allocation) problem. This framework enhances the designer's ability to analyze and capture the behavior of different circuit blocks and pass the design-space information for each block to the system designer.

Taken together, these techniques can alleviate or completely remove the chip communication bottleneck. By advancing the design of chip-to-chip interfaces through energy-efficient coding and communication techniques, novel architectures and hierarchical optimization, we aim to open the way to creating extremely powerful data networks and computing devices.

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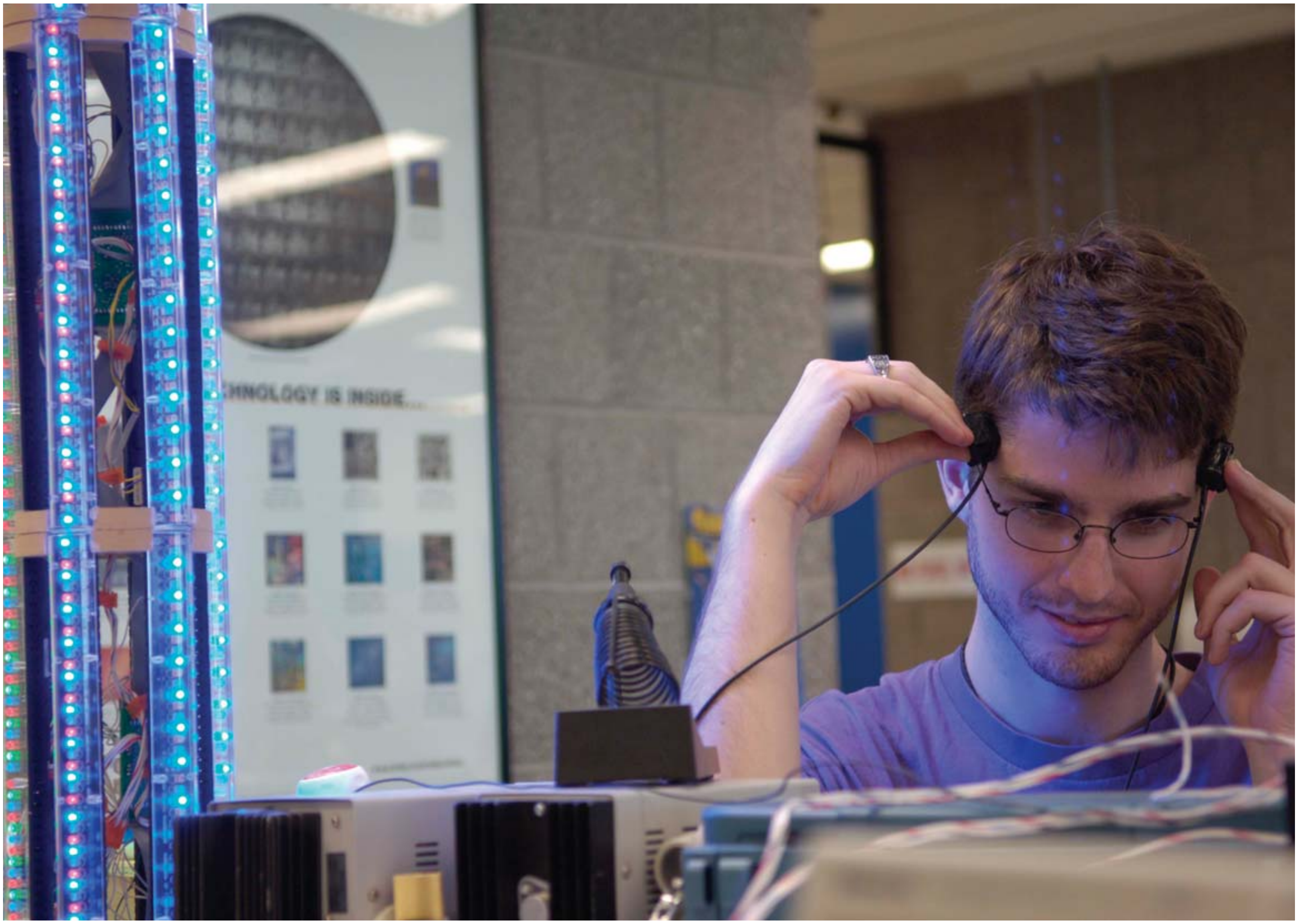

Brian Neltner, MIT DMSE graduate student, works at his project in 6.115, Microcomputer Project Laboratory. The idea of this project was to build a simple EEG amplifier, and use the 8051 microcontroller to analyze the output signal. Spring, 2006

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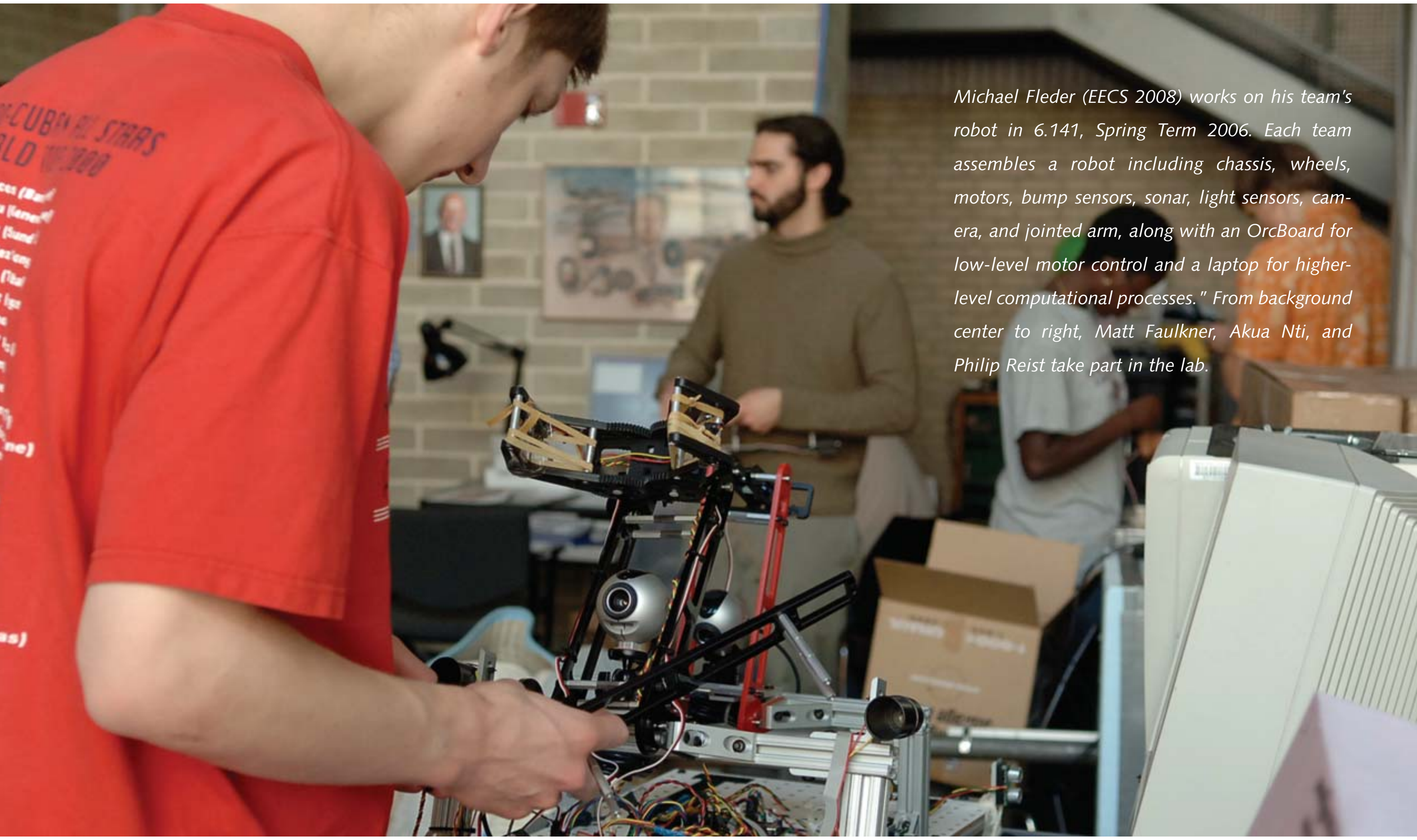

Michael Fleder (EECS 2008) works on his team's robot in 6.141, Spring Term 2006. Each team assembles a robot including chassis, wheels, motors, bump sensors, sonar, light sensors, camera, and jointed arm, along with an OrcBoard for low-level motor control and a laptop for higher-level computational processes." From background center to right, Matt Faulkner, Akua Nti, and Philip Reist take part in the lab.

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