

Winter 2010

AERO 345 [Bernstein]

AERO 573 [Kolmanovsky]

AERO 584 [Kabamba]

EECS 460 [Meerkov]

EECS 461 [Cook]

EECS 498 (Special Topics: Introduction To Discrete Event Systems)
[Lafortune] <http://www.eecs.umich.edu/eecs/etc/news/shownews.html>
(Note: EECS 661 will NOT be offered in Fall 2010).

EECS 498 (Special Topics: Bio-molecular Feedback Systems)[Del Vecchio]

EECS 498 (Special Topics: Electric Machinery and Drives)[Hoffman]

EECS 498 (Special Topics: Grid Integration of Alternative Energy
Sources)[Hiskens]

EECS 502 [Teneketzis]

EECS 562 (Aero 551) [Girard]

EECS 565 (Aero 580) [Freudenberg]

EECS 692 (Special Topics in AI: Robot Learning)[Kuipers]
<http://eecs.umich.edu/~kuipers/teaching/eecs692-W10.html>

ME 542 [Gordon]

ME 561 (EECS 561) [Oldham]

ME 567 (EECS 567) [Moore]

ME 400/599 (Special Topics: Vehicle Electrification: Battery Systems and
Control) [Fathy and Stefanopoulou]

ME 400/599 (Special Topics: Vehicle Electrification: Hydrogen and Fuel
Cells) [Siegel and Stefanopoulou]

Bio-molecular Feedback Systems

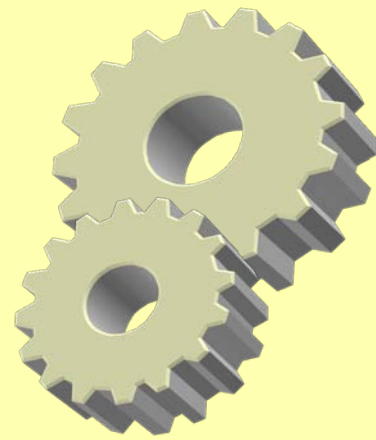
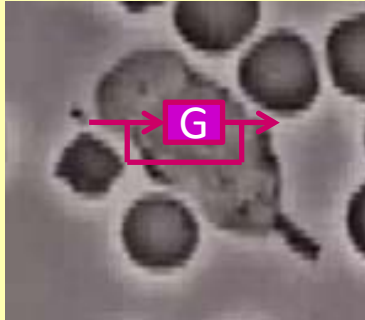
Instructor:

Prof.

Domitilla

Del Vecchio

ddv@umich.edu



**EECS 498
Special Topics
Course**

Objectives: The course will illustrate basic feedback mechanisms that living organisms implement at the molecular level to execute their functions. The emphasis will be on analogies/differences with man-made control systems and on how to re-engineer feedback systems at the molecular level to control cellular behavior. By the end of the course, engineering students should be convinced that feedback systems go far beyond what is taught in standard systems/control courses; non-engineering students will learn how biological functions can be deeply understood using notions from feedback systems; everyone will have learned that biology offers a rich set of inter-changeable building blocks that, just as legos, can be composed to obtain new cellular behaviors.

Topics: Part 1: Analysis. Basic concepts of biology, central dogma, regulation mechanisms, simple ODE models for biomolecular systems, feedback, adaptation and integral feedback (e.g., chemotaxis), noise, signaling systems and amplification (e.g., MAPKK cascades), oscillators and delayed negative feedback (e.g., circadian rhythms). Part 2: Design. Basic enabling technologies (fabrication, implementation, measurement), examples of simple synthetic bio-molecular modules (oscillators, memory systems, inverters, filters, noise rejection systems), interconnection of modules, impedance problems (i.e., retroactivity), insulation devices and feedback.

Prerequisites: Undergraduate-level linear algebra and calculus, basic probability, A first course in control systems such as EECS 460 is desirable, but not required.

Audience: seniors in control systems interested in biology, graduate students in systems and mathematics interested in biology, graduate students in bioinformatics, physics, and biology interested in exploring new tools for analysis and design

EECS 498: Electric Machinery and Drives

Winter 2010



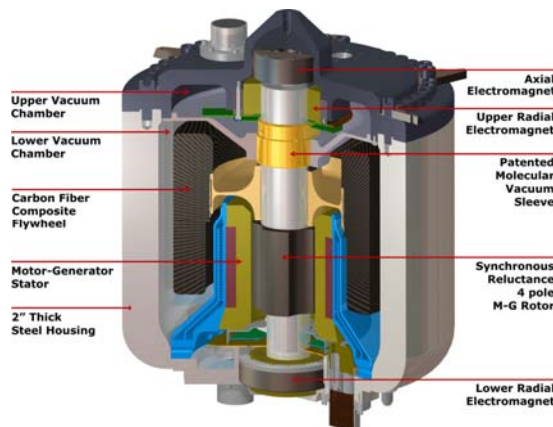
Tesla Roadster

Each of these systems contains: an electric machine operating either as a motor, a generator, or both; a power electronic circuit which interfaces the machine to a power supply or an electrical system; and a controller which measures electrical and mechanical quantities and uses this information to control the power electronic circuitry.

In the struggle to address today's energy and environmental challenges, many potential solutions require electro-mechanical energy conversion. Examples include electric propulsion drives for electric and hybrid electric vehicles, generators for wind turbines, and high-speed motor/alternators for flywheel energy storage systems.



Wind Turbines



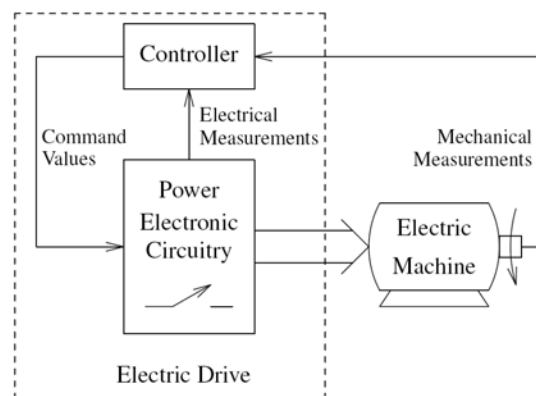
Flywheel Energy Storage

In this course we will cover fundamental electromechanical, power electronic, and control theory in the context of electric drive systems. The capabilities and limitations of different types of electric machines (e.g., permanent magnet, induction) in various drive applications will be covered. MATLAB® Simulink® models will be used throughout the course to give students exposure to the dynamic behavior of these systems.

Lectures: Tuesday & Thursday 12-1:30
Wednesday 12-1

Instructor: Prof. Heath Hofmann
(hofmann@eecs.umich.edu)

Prerequisites: EECS 216 (or equivalent; material will also be accessible to students in non-EE disciplines)





EECS 498 Special Topic Grid Integration of Alternative Energy Sources

**Wednesday, 8:30-10:30am and Friday, 10:00am-Noon
Winter 2010**

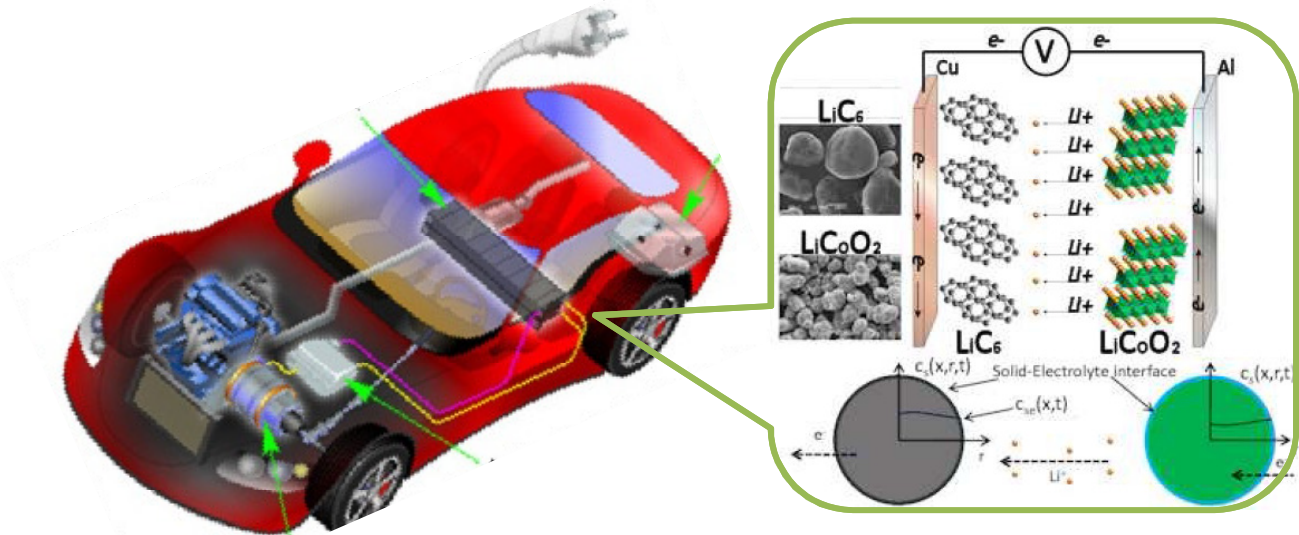
The course will present a variety of alternative energy sources, along with energy processing technologies required for power system connection. System integration issues will be addressed, with consideration given to impacts on current design philosophies and operating procedures. Topics will be covered at a level suited to establishing a broad understanding of the various technologies, and of the associated system implications. The course will develop tools necessary for analysis and design of alternative energy systems.

Syllabus:

1. Power systems: basic concepts, system operation.
2. Wind power: basic principles of wind energy, electromechanical energy conversion, optimal power extraction.
3. Power electronic converters: switches, diodes, basic converter topologies.
4. Photovoltaic (PV) cells: energy conversion principles, electrical modeling, optimal power extraction.
5. Other alternative energy sources: fuel cells, wave power.
6. Energy storage technologies.
7. Plug-in hybrid electric vehicles: basic operating principles, grid interconnection strategies and issues.

Prerequisites: EECS 215 or 314 (or Permission of Instructor).

Course Director: Prof Ian Hiskens, Electrical Engineering and Computer Science.
For additional information contact <hiskens@umich.edu>.



MECHENG 499-006/599-006 Special Topics Course

Vehicle Electrification (Part A): Battery Systems and Control

Winter 2010, Jan 6-Feb24

Monday and Wednesday, 3:30-5:30

Chrysler Center 165 – 2 Credits

This course covers battery modeling, control and diagnostic methodologies associated to battery electric and battery hybrid electric vehicles. Emphasis is placed upon system-level modeling, model order reduction from micro-scale to macro-scale and surrogate models for load control, estimation, on-board identification and diagnostics for Lithium Ion batteries. The electrochemical, electrical, and transport principles for battery modeling are reviewed. Spatiotemporal models of coupled concentration, potential, and thermal phenomena are introduced and then augmented to predict aging and capacity fade. Simulation of the resulting partial differential equations using various popular software tools will be introduced with selected topics on numerical issues. Time- and frequency-domain model order reduction techniques, system identification, parameter estimation, filtering, and control theory will be covered and applied to state of charge, state of health, load governors and rate limiters. Additionally, electric-circuit battery models, DC/DC converters, and other vehicle implementation issues of power management and balancing will be introduced.

This course comprises the first part of a 2-course sequence beginning with MECHENG 499/599-007 [Vehicle Electrification (Part B): Hydrogen and Fuel cells

Intended audience: Junior-level+ undergraduates or graduate students with an interest in vehicular energy storage and conversion.

Grading: A combination of mini-projects and quizzes will be used. A term paper will be required from the graduate students. Two separate grade curves will be applied for the 499 and the 599 registration.

Prerequisites: ME360

Instructors: Dr. Hosam Fathy and Anna Stefanopoulou , Mechanical Engineering Dept.

For additional information: hfathy@umich.edu or annastef@umich.edu



MECHENG 499-007/599-007 Special Topics Course

Vehicle Electrification (Part B): Hydrogen and Fuel Cells

Winter 2010, March 8-April 19
Monday and Wednesday, 3:30-5:30
EECS 1303 – 2 Credits

This course covers essential aspects of fuel cell vehicle technology, hydrogen fueling infrastructure, and potential benefits & barriers to the use of hydrogen as a vehicular fuel. Emphasis is placed upon system-level modeling and control issues of polymer electrolyte membrane fuel cells and on the principles and design of on-board hydrogen storage systems. Hydrogen generation and distribution technologies are introduced, and life-cycle (well-to-wheels) analyses of petroleum consumption, efficiency, and CO₂ reduction are presented. Lectures will be supplemented with fuel cell vehicle demonstrations conducted by local automotive OEMs, and site visits to hydrogen fueling stations.

This course comprises the second part of a 2-course sequence beginning with MECHENG 499/599-006 [Vehicle Electrification (Part A): Battery Systems and Controls]

Intended audience: Junior-level+ undergraduates or graduate students with an interest in vehicular energy storage and conversion.

Grading: A combination of mini-projects and quizzes will be used. A term paper will be required from the graduate students. Two separate grade curves will be applied for the 499 and the 599 registration.

Prerequisites: ME382 or MSE360 and ME360

Instructors: Profs. Don Siegel and Anna Stefanopoulou, Mechanical Engineering Dept.

For additional information: djsiege@umich.edu or annastef@umich.edu

Embedded Control Systems Education at the University of Michigan

By Professors Jim Freudenberg and Jeff Cook, University of Michigan

IN 1999, SENIOR RESEARCH ENGINEERS AT ONE OF DETROIT'S "BIG THREE" automotive OEMs drew our attention to the shortage of graduating seniors fully prepared for careers in embedded systems engineering. While new electrical engineers have a good grasp of signal processing and control theory, many have never implemented a control system on an embedded processor. Likewise, recent graduates in computer engineering understand microprocessor hardware and programming but are less familiar with control design, signal processing, and the challenges of implementing real-time embedded systems.

The key to bridging this gap was to educate teams of electrical and computer engineers to collaborate on cross-disciplinary projects, where they learn to develop algorithms and implement them on hardware. Under the guidance of Detroit engineers, and with the invaluable assistance of numerous graduate students over several years (especially Noah Cowan, now a professor of mechanical engineering at Johns Hopkins University), University of Michigan developed an elective course for seniors and first-year graduate students in both engineering disciplines. Throughout the semester-long course, students are exposed to industry-standard tools and technologies, and to Model-Based Design for embedded control systems.

EECS 461: Embedded Control Systems

The course is built around a series of labs employing the Freescale™ MPC5553 microprocessor and a "haptic wheel" designed by Professor Brent Gillespie in the Department of Mechanical Engineering.

Students use the knowledge gained in eight laboratory exercises over the course of a semester to design and implement a driving simulator using the haptic wheel to steer a mathematical vehicle model along a virtual road. Ultimately, every team's driving simulator is connected via a Controller Area Network (CAN) and simulated on a single road. Students implement an adaptive cruise controller to maintain a preset distance between virtual cars on the road.

Integrating Lectures and Lab Assignments

EECS 461 incorporates three hours of lectures and three hours of laboratory work each week. We introduce each new system and control concept in the lecture, typically with a homework assignment employing Simulink® and Stateflow®. The concepts are then applied in the lab using a different peripheral device on the MPC5553 each week. For most of the course, students interface with hardware and implement algorithms by hand-coding in C. This helps them understand the microprocessor architecture, the operation of peripheral devices, and the intricacies of low-level device-driver programming.

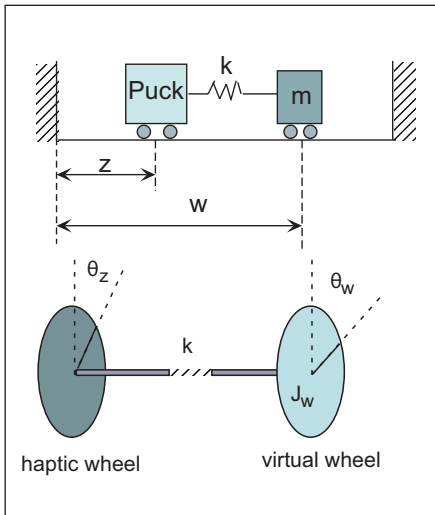


FIGURE 1. Virtual spring-mass system.

In the first lab, students employ a University of Michigan–designed interface to the microprocessor containing two banks of digital input DIP switches and a bank of LED displays connected to digital output pins. The exercise is straightforward: Two binary values are input using the DIP switches. The values are summed, and the result output to the LEDs. In subsequent labs, students program queued

analog-to-digital conversion and examine issues of sampling and signal aliasing. They use the optical encoder and quadrature decode function of the MPC5553-enhanced Time Processing Unit (eTPU) to measure the position of the haptic wheel. In a related homework problem, students model the quadrature decode operation of the microprocessor using Stateflow.

In the fourth week, students program the MPC5553 to generate a pulse width modulated (PWM) signal to control the speed and direction of the haptic wheel and implement two simple haptic virtual worlds: a virtual spring, in which a restoring torque is generated proportional to the wheel angular displacement, and a virtual wall, in which the wheel is permitted to rotate freely up to a specified displacement, at which point the motor generates a strong restoring force, or virtual wall.

The following lab introduces interrupt processing: A sine wave from a signal generator is periodically sampled and its value used to modulate the duty cycle of a PWM signal. The input signal is then reconstructed from the PWM signal using a low-pass filter to attenuate the high-frequency content, leaving only the

sinusoidal modulation frequency. Concurrently, students model the DC motor in Simulink and investigate PWM motor control in simulation.

By this point, students have developed the ability to implement complex virtual worlds with haptic feedback incorporating various connections of walls, dampers, and springs. They design a virtual knob that gives the user feedback—detents that can be felt at regular intervals. A virtual spring-damper adds a retarding force proportional to wheel angular velocity to the virtual spring developed in an earlier lab. Virtual spring-mass and spring-mass-damper systems (Figure 1) require students to deal with implementation and numerical instability issues involved in Euler integration. Students model dynamic systems in Simulink, where they evaluate differences between continuous and discrete implementations and the effects of integration methods. In the penultimate lab exercise, they investigate issues of networked control by distributing each team's virtual spring across a CAN network to form a virtual chain. In this way, displacement of a wheel at one end of the chain propagates through each of the six connected haptic devices.

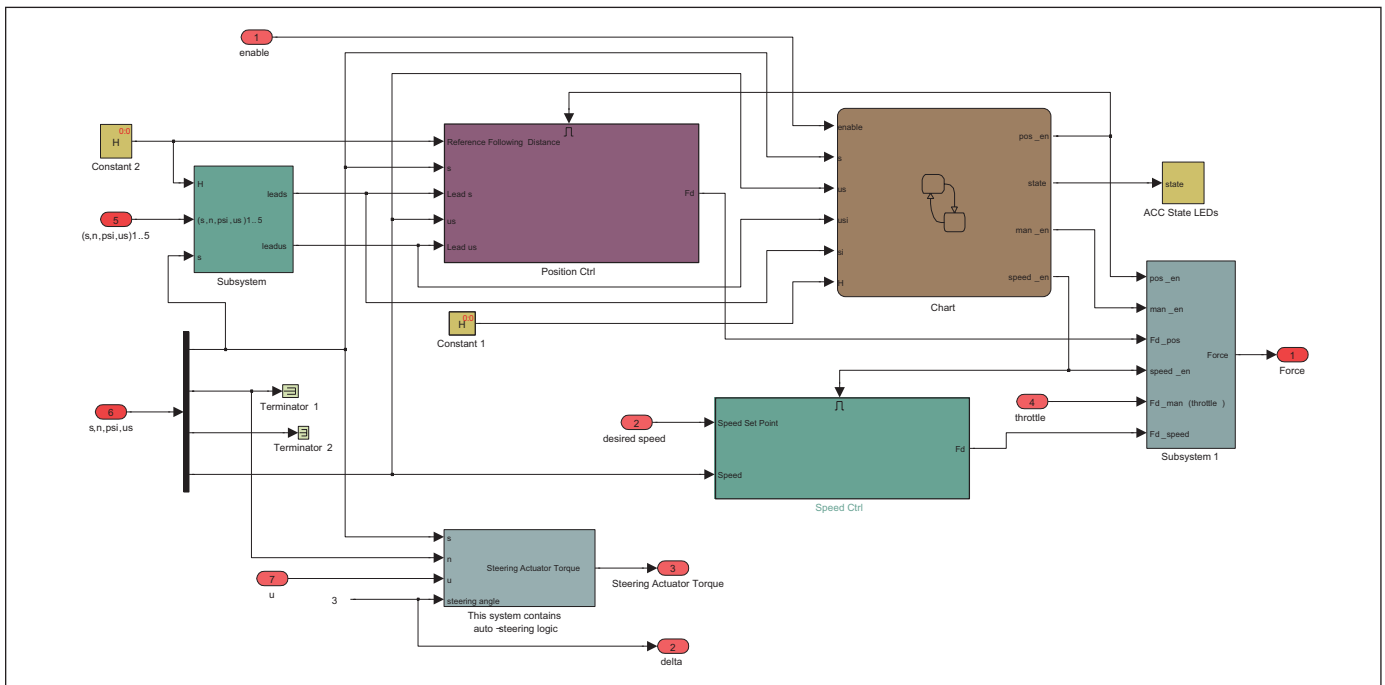


FIGURE 2. Simulink model of two virtual systems.

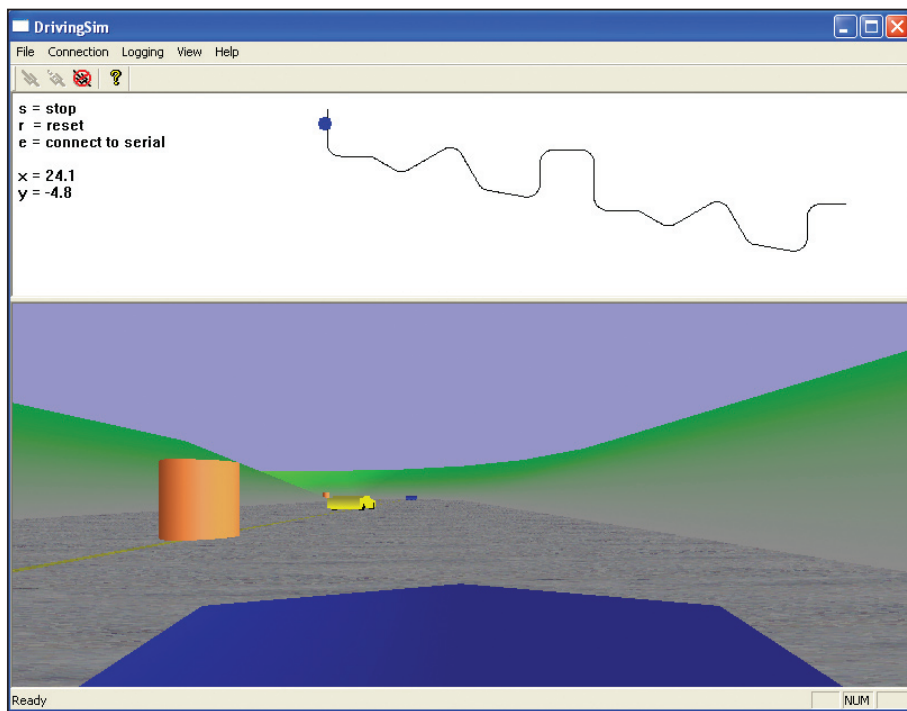


FIGURE 3. Adaptive cruise control simulation.

In the lab that precedes the final project, we introduce rapid prototyping and code generation using Real-Time Workshop® and Real-Time Workshop Embedded Coder™. In lecture, we discuss the advantages of Model-Based Design, emphasizing the ability to debug and verify control systems before implementing them in hardware and the importance of eliminating the gap between control design and controller implementation.

The students reimplement the virtual wall exercise that they completed in an earlier lab, this time using code generation. They compare the efficiency and structure of their hand-coded implementation with the generated code. They then create a Simulink model to simulate a virtual world with two spring-inertia-damper systems coupled to the haptic wheel (Figure 2). The two systems have significantly different time constants, and thus require a multitasking solution. This lab highlights the time savings that rapid prototyping can provide in the development of complex embedded control systems.

Designing an Adaptive Cruise Control System

For the final project, which lasts about four weeks, student teams implement their driving simulators entirely in code generated from Simulink and Stateflow models. Stateflow is particularly valuable in describing the three required operating modes: *manual*, in which the speed of the virtual car is controlled by a potentiometer on the interface board; *constant speed*, which is much like the cruise control systems in vehicles today; and *constant distance*, in which the virtual vehicle maintains a distance between itself and the virtual car in front determined from speed and position data broadcast over the CAN bus from each team's simulator (Figure 3).

Meeting the Demand for Embedded Controls Engineers

EECS 461 graduates have gone on to work for leading automakers and suppliers, semiconductor companies, appliance manufac-

turers, and aerospace companies. A former student now working at a tier-one automotive supplier recently wrote to tell us, "The tools and information that I learned in EECS 461 have done more for me than any other class at the university." Another student was hired for an internship at a leading automotive supplier after she told the interviewer of her course experience with Simulink, Stateflow, and the adaptive cruise control system.

In some cases, employers from other states have paid for staff to temporarily relocate to Michigan in order to take the course. We've had professional engineers who were already employed locally sign up for the course, and we know of others who were hired on condition that they complete the course before beginning work.

Recently, EECS 461 has "gone international." For the first time last September, Professor Lino Guzzella of the Swiss Federal Institute of Technology (ETH) brought the course to Zurich, where it was taught by Jeff Cook. This year, Jim Freudenberg will teach the course at ETH.

Between 80 and 100 students enroll in EECS 461 each year, a number limited only by how many students can be accommodated in the laboratory. Ten years after our initial discussion with the OEM, the continued interest from students and industry tells us that EECS 461 is extremely valuable to students and makes our students valuable to industry. ■

Resources

UNIVERSITY OF MICHIGAN
DEPARTMENT OF ELECTRICAL ENGINEERING
www.eecs.umich.edu

CURRICULUM EXCHANGE
www.mathworks.com/nn9/curriculum