2006-2332: MEMS AND MICROSYSTEMS COURSES WITH NATIONAL AND INTERNATIONAL DISSEMINATION

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MEMS and Microsystem Courses with National and International Dissemination*

Abstract

The Wireless Integrated MicroSystems (WIMS) Engineering Research Center (ERC) has developed a broad comprehensive MEMS and microsystem curriculum suitable for upper-level undergraduate students, graduate students, and industry professionals. Five core courses were in the initial curriculum design. The design had flexibility that invited development of other core courses, as well as related technical electives and breadth electives. The core courses provide instruction in MEMS, Microsystems, major design and laboratory measurements, and societal impact. The course enrollments have been strong. A master of engineering in integrated microsystems degree program was developed so that industry professionals would have a focused set of coursework, while providing flexibility that would permit custom tailoring of the total course package to serve specific needs. Distance education dissemination of the courses as whole courses, or as discrete portions of course materials, was intended to be available; that goal has been realized. The core courses originate at the University of Michigan (UM), and have been distributed to Michigan State University (MSU), Michigan Technological University (MTU), Howard University (HU), University of Puerto Rico – Mayaguez (UPRM), and Western Michigan University (WMU). Rochester Institute of Technology (RIT) has used materials from the UM core courses in its offerings. Other institutions that have used the course web-streaming video and course materials are University of Lille, Darmstadt University, and Middle East Technical University.

Introduction and Overview

The Engineering Research Center for Wireless Integrated MicroSystems (WIMS ERC) has developed five core courses (Figure 1) that provide a broad comprehensive curriculum in MEMS and microsystems for upper-level undergraduate students, graduate students, and industry professionals. The five core courses originate at the University of Michigan (UM): *Introduction to MEMS* (EECS 414), *Integrated Microsystems Laboratory* (EECS 425), *Advanced MEMS Devices and Technologies* (EECS 514), *Advanced Integrated Microsystems* (EECS 515), and *Societal Impact of Microsystems* (EECS 830). The first of these courses has now been disseminated worldwide, while the second is exploring ways of porting a laboratory course to different universities. The *Societal Impact* course explores the global societal challenges that will be faced by students during their careers and how microsystems will be used to address them. Each course is a four credit-hour course, except EECS 830 is a two credit-hour course.

During a two-day education retreat, the MEMS/Microsystem curriculum was designed to (1) provide students with a comprehensive background in MEMS/microsystems theory, fabrication, practice, applications, and technology, (2) accommodate students from broad disciplines across science and engineering by developing a first course that had minimal prerequisites in science (physics and chemistry), math, and engineering, (3) use the first course as the only prerequisite for the remaining core courses, (4) develop course materials with the expectation that distance education with web-based dissemination would be a primary format, (5) serve undergraduate and graduate students, as well as serve practicing professionals, (6) be available for students at all three partnering universities (UM, MSU, MTU), (7) develop skills in critical assessment of diverse technologies and devices, (8) develop engineering project management skills, (9) be a core set of requirements for a graduate professional degree program to accommodate practicing professionals desiring an advanced degree, and (10) be flexible enough to encourage creation of other courses with links to broad interdisciplinary areas. All of these design goals have been met (and in many cases exceeded), with strong student enrollment in all the core courses at WIMS ERC partnering universities. Several of the courses have been adopted by other universities, nationally and internationally. Curriculum approvals and local course numbers have been obtained at Michigan State University and Michigan Technological University. Also, these courses have been used at Western Michigan University, University of Puerto Rico – Mayaguez, Howard University, and Rochester Institute of Technology in the United States, and internationally at the University of Lille, Darmstadt University, and Middle East Technical University.

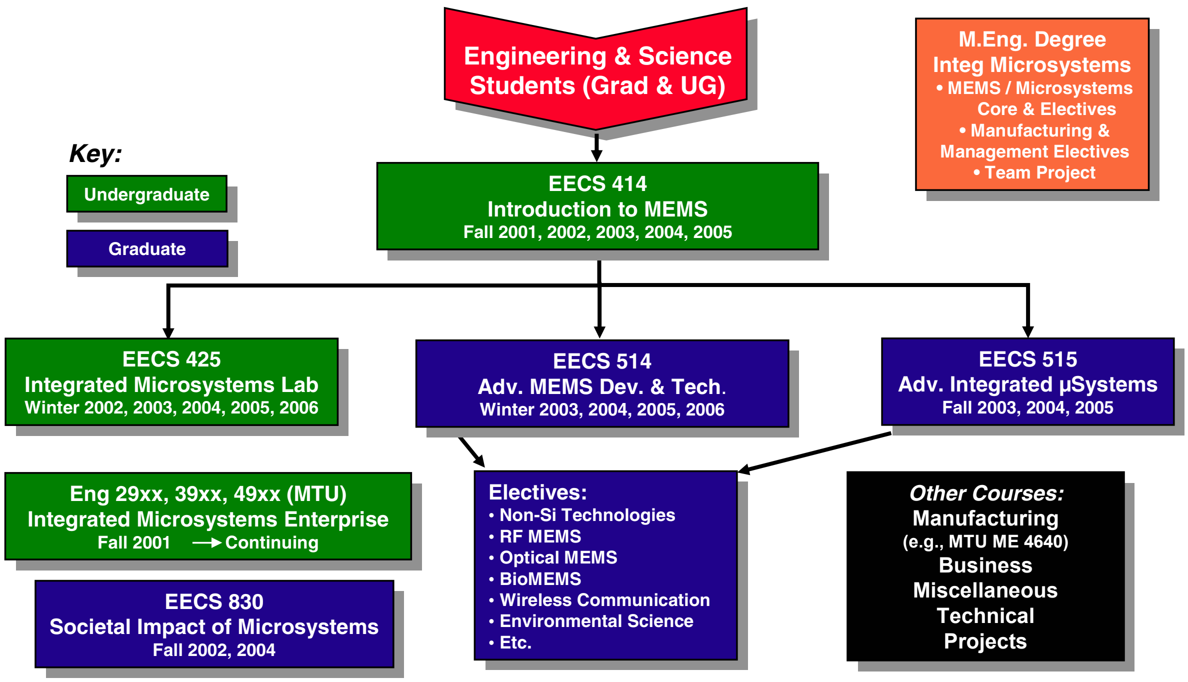


Figure 1. MEMS and Microsystems Curriculum Design for WIMS ERC

The following segments of this paper describe ways that the goals were addressed and have progressed. Associated curriculum issues for each course from EECS 414 to EECS 830 are presented in this paper. Enrollment in each course is presented in a table including all courses. Factors associated with distance education and a master of engineering degree program are presented. A list of acronyms is included at the end of this paper.

Introduction to MEMS (EECS 414)

One of the main challenges in MEMS education has been teaching the ***first*** course to novice ***undergraduate*** students. Several questions immediately arise as one begins to prepare such a course. Who is taking the course and what backgrounds do they have? What should be the prerequisites, if any? Should the first course be available to most engineering students, or should access be limited by adding one or several prerequisites? When is the right time to take this course? What should be taught in the course, what should be the balance between theory and practice/technology, and what is the objective of the course? Should it have a lab component, should it have a major design project, or should it have several projects? Should design and software tools be taught? If the course is available to both undergraduate and graduate students, how can they be accommodated in a single course, or should they be? What does/would industry like to see in this course? Is one course sufficient to prepare students for practicing MEMS in industry? Undoubtedly many institutions have faced these and other questions as they attempted to prepare such a course. A few answers/decisions for these questions are presented here, along with the philosophy and experience gathered at the University of Michigan over the past five years since we started teaching an "Introduction to MEMS" course and have made it available to practically all engineering and science students with an interest in learning about MEMS.

We believe that the first course should be open to all students irrespective of their discipline. The only requirements are basic math, physics, chemistry, and a basic background in electrical and mechanical physics as is typically offered in most engineering/science curricula. This introductory course is designed for students who are not familiar with MEMS, microfabrication and micromachining technologies, integrated circuits, or nonelectrical devices and systems. The course has discussion sections that enhance both mechanical and electrical background areas for science majors (such as physics and chemistry majors, etc.) and other engineering majors (such as non-EE and non-ME) students. The course has also been taken via the internet by students at several other institutions, and challenges in this area have been identified.

Since micromachining technology affects all aspects of MEMS, the course starts with a detailed coverage of microfabrication and micromachining, including planar thin-film processes, photolithographic techniques, deposition and etching techniques, wafer bonding, and electroplating. These topics are followed by a detailed coverage of surface, bulk, and electroplating micromachining technologies and review of example devices. A designer of MEMS requires knowledge and expertise across several different disciplines. Therefore, this course pays special attention to teaching of fundamentals of transduction mechanisms (i.e. conversion of non-electronic signals to electronic signals), including capacitive, piezoresistive, and thermal techniques, and design and analysis of micromachined sensors and actuators. The course also introduces students to MEMS-specific CAD tools, including Coventorware and ANSYS. Weekly assignments allow students to use CAD tools to simulate a few sample structures and compare their operation to calculated values.

Figure 2 summarizes the topics covered in EECS 414 (highlighted in blue) in the context of all topics that we think eventually should be covered in an effective MEMS curriculum. The first course *Introduction to MEMS* (EECS 414) is the only prerequisite needed for follow-on courses. During its first offering in Fall Term 2001, a textbook *Microsystem Design*[1] was designated. After that term, the reading materials resources have been course notes and PowerPoint slides that were developed by UM faculty, as well as numerous designated journal and conference articles[2-4]; these resources better match the content and flow of the course. These resources have been readily shared and provided to others who seek to develop a course at their institution.

Materials/Fabrication

- Materials
  - Silicon & related semiconductors
  - Non-Silicon
- Micro Fabrication
  - Photolithography
  - Planar microfabrication
- Micromachining
  - Photolithographic (parallel)
    - Planar
    - Si etching & machining
  - Non-photolithographic (serial)
    - Non-planar, 3D
    - Standard precision machining

Transducers

- Energy Domains
  - Electrical
  - Mechanical
  - Thermal
  - Chemical/Gas/Bio
  - Optical, Radiative
- Transduction Techniques
  - Capacitive
  - Piezoresistive
  - Thermal
  - Magnetic
  - Piezoelectric
  - Resonant
  - Tunneling
  - Optical/Radiative
  - Others...
- Sensors
- Actuators

Microsystems

- Circuits
  - Sensor &Actuator
  - A-D conversion
- System
  - Architecture, partitioning
  - Signal processing
- Power Issues
  - Power/Energy source
  - Power dissipation
  - management
- Noise and Signals
  - Sources,limits
- Communication
- Testing & Calibration
- Integration
- Package

Figure 2. Content Topics for Three Core Courses

LEGEND:

Blue Font: *Introduction to MEMS* (EECS 414);

Black Font: Advanced MEMS Devices and Technologies (EECS 514);

Red Font: Advanced Integrated Microsystems (EECS 515)

Table 1 shows the enrollment in the course (at all institutions), including the breakdown of undergraduate and graduate students taking the course at the University of Michigan for the past five years. Although the course was at first taken mostly by graduate students, it now has a 2:1 ratio of undergrads to grads. This trend clearly indicates the growing interest in MEMS as a discipline often required by industry.

Table 1. Enrollment History by Groups in *Introduction to MEMS* (EECS 414)

	2001	2002	2003	2004	2005
UM Undergraduate Students	20	26	61	52	57
UM Graduate Students	37	40	43	25	26
UM Total Students	**57**	**66**	**104**	**77**	**83**
USA Univ. Distance Educ. Students	25	23	42	45	48
USA Total Students	82	89	146	122	131
Industry Distance Education Students			3	5	3
International Distance Educ. Students		29	20	31	64
Total Students Worldwide	**82**	**118**	**166**	**158**	**198**

EECS 425 Integrated Microsystems Laboratory

In this one-semester laboratory course, students work in four-person teams; they define, design, fabricate, and test a microsystem of their choice. The microsystems realized typically consist of a two-chip combo: a transducer chip and a circuit chip, fabricated over the course of a 14-week semester (six weeks in microsystem design, five weeks in fabrication, and three weeks in test). The course accepts senior and first-year graduate students from either a device/circuit or MEMS background and serves as a major design experience for undergraduates. It allows students to understand the interactions among design, fabrication, and test, and for many this course is the only chance they will ever have to take a chip all the way from inception to final test. Students come from various engineering majors (electrical, mechanical, biomedical, and chemical), as well as from physics.

Figure 3 shows the activity flow for the course, consisting of two 80-minute lectures per week plus one 3-hour laboratory session. The lectures are taped and available over the web, permitting the course to be taken at other universities (currently Michigan Sate and Michigan Tech) with an on-site instructor. Designs created elsewhere are fabricated at Michigan (while those students fabricate test devices in their own laboratories) and are then returned to them for testing. For the circuitry, a five-mask ion-implanted silicon-gate LOCOS E/D NMOS process is used. While this process lacks the performance of a full CMOS process, it can be run in five weeks or less and exposes students to a full range of process steps. For the transducers, a silicon-on-glass (dissolved-wafer) process is used, allowing a wide range of devices to be realized in six masks and allowing wafer bonding and diffused etch-stops to be illustrated. The students are given the processes and a 2mm x 2mm die area for each chip and are challenged to get the best performance they can from whatever design they elect to realize.

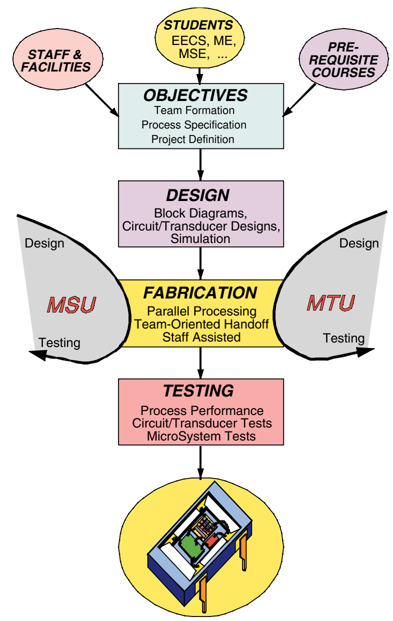


Figure 3. Activity Flow For *Integrated Microsystems Laboratory* (EECS 425)

Figure 4 shows a die photograph and close-up of a typical transducer die, while Figure 5 shows one of the circuits realized in the course along with one team in cleanroom garb. Mask fabrication and ion implantation are done in foundries, with students performing all other processing steps except for those processes involving chemical vapor deposition, which are done by engineering staff. Visible imagers, pressure sensors, accelerometers, g-switches, tactile imagers, micro-flowmeters, micro-mirror arrays, mass sensors, and Pirani gauges have been realized. The course projects often find their way into student resumes and occasionally receive broader exposure. A project two years ago won second place in the Design Automation Conference (DAC) student design contest and was featured there and at the International Solid-State Circuits Conference.

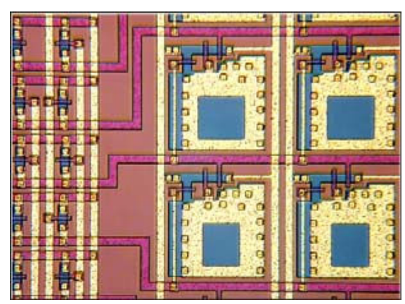


Figure 4. Visible Imager Transducer Die for *Integrated Microsystems Laboratory* (EECS 425)

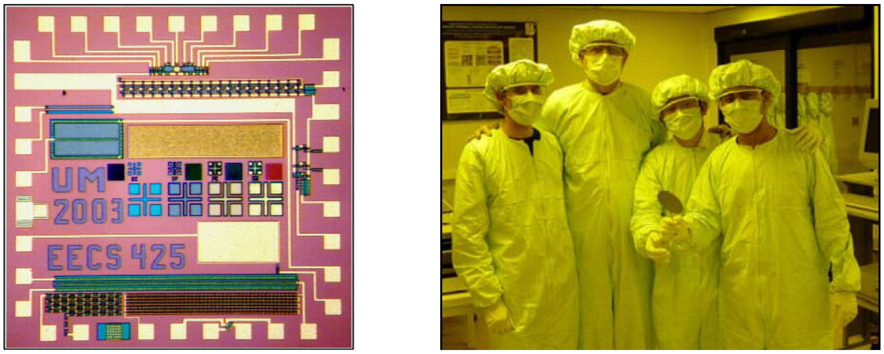


Figure 5. An IC produced in the *Integrated Microsystems Laboratory* (EECS 425) course and a photo of students in the cleanroom

Advanced MEMS Devices and Technologies (EECS 514)

EECS 514 is largely an Advanced MEMS Technologies course as it continues the MEMS topics started in EECS 414, as indicated in the Figure 2 list of topics. EECS 514 covers advanced topics dealing with MEMS technologies, transduction mechanisms, and microfabricated sensors and actuators. Many emerging micromachining technologies, such as laser and electro-discharge micromachining, and nonconventional materials, such as silicon-carbide and diamond are discussed. Transduction techniques, including electromagnetic, piezoelectric, resonant, tunneling, and others are presented. The course reviews different types of sensors for measurement of physical parameters such as acceleration, rotation rate, and pressure, as well as chemical and gaseous parameters for gas and chemical sensing applications. It also reviews different micro-actuation techniques and their application in MEMS. The course also reviews MEMS for use in microfluidics and in biomedical applications. An important part of this course is a design project carried out in teams who develop, simulate, and design a device of their choice, and present their findings in a technical article. MEMS-specific CAD tools such as Coventorware and ANSYS are used to design and model the devices. The course is highly structured, with two intermediate presentations and a final one at the end of the course. Typically, students read 25 to 40 papers[5-7], and 6 to 8 student reports. A highlight assignment is students working in teams to develop sensor or actuator concept MEMS; see Figure 6 for a sample of three concept projects. The concept of an NSF-style panel discussion and peer review procedure is discussed. (However, the reports are not written in proposal style, and the students are not expected to project beyond their findings to propose work that will be done in the future. That approach comes up in EECS 515.) All students provide individual assessments of all projects at the end of the course. Students have been from several engineering majors: electrical, mechanical, biomedical, and chemical engineering, as well as from applied physics. All course materials, including lecture notes and lecture videos, are available via the web.

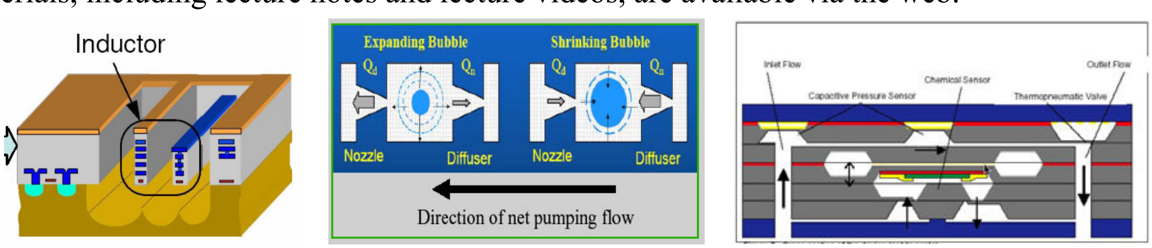
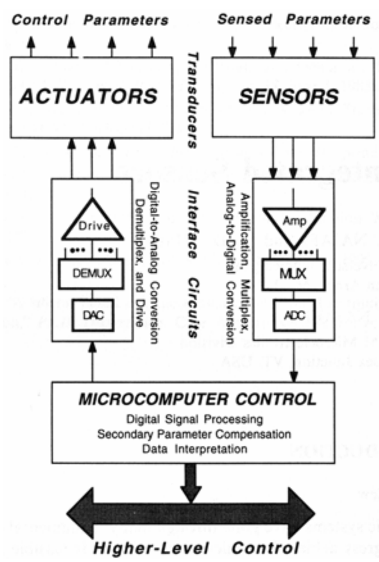


Figure 6. MEMS Concept Projects for *Advanced MEMS Devices and Technologies* (EECS 514): Inductor, Microfluidic, and Integrated Sensors Devices

Advanced Integrated Microsystems (EECS 515)

EECS 515 is an Advanced Integrated Microsystems course, building upon the MEMS topics and microsystems introduction presented in EECS 414. Prerequisites for this course include the equivalent of EECS 414 or EECS 514, and graduate standing. The students are also expected to have a working knowledge of basic analog circuits. It is desired that students would have completed EECS 425, but not required. EECS 515 is the third in the 414, 514, 515 trio of courses that was developed as part of the MEMS/Microsystems core curriculum (with topics identified in Figure 2). As such, it is directed primarily at graduate students and industry professionals who have already achieved a level of comfort with MEMS technology, and are familiar with the important transduction methods, device concepts, and fabrication techniques. As in EECS 514, students read 25 to 40 papers[5-7], and 6 to 8 student reports. For EECS 515, a highlight assignment is students doing an NSF-style proposal centered around a microsystem design to solve an application; see Figure 7 for a microsystem design template, and a diagram for a cardiac stent microsystem project.



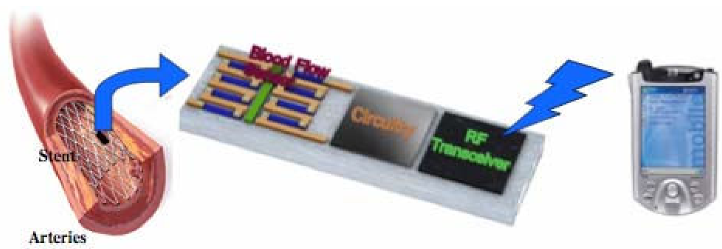


Figure 7. Microsystem Design Template and Cardiac Stent Microsystem Project for *Advanced Integrated Microsystems* (EECS 515)

The topics covered in this course are a mix of device and circuit issues that are closely inter-related and are critical to a full understanding of microsystems. They include, for example, general ways to analyze noise in electronics and sensors; various kinds of interface circuits for capacitive, resistive, tunneling and other kinds of sensors; proportional integral controllers; dithering and modulating circuits; switched-capacitor interface circuits; correlated double-sampling; calibration schemes; system organization; digital bus protocols for transducer systems; packaging; and cost projections. The topics are relevant to both industrial practice and microsystems research, and address both fundamental and practical problems that arise in this field of engineering. An important part of this course is the team project, which requires students to develop research proposals that are then reviewed by the class in NSF-style panels, using both technical merit and broader impact as evaluation criteria. The EECS 515 project bears similarity to the project in EECS 514, but with important differences: a) The project report is written proposal-style, so the work performed during of the semester is intended to provide convincing preliminary results for the proposal. The students are encouraged to think of the strategic end goals, and determine the best minimum set of calculations, simulations, and analysis to address them. b) The proposals are required to include systems aspects, and thus must cover a circuit in addition to a sensor or actuator. c) Budgeting and milestone planning for the proposed work are required. Students have been from several engineering majors: electrical, mechanical, biomedical, and chemical engineering, as well as from applied physics. This course is available to distance education students via the web.

Societal Impact of Microsystems (EECS 830)

During the next two decades, microsystems are expected to have a pervasive impact on society as they are used to couple electronics to the non-electronic world. Microsystems will be used to monitor our environment (global warming, pollution, improved weather forecasting), provide homeland security, improve transportation systems (vehicles and infrastructure), and spark dramatic progress in health care (genetics, proteomics, wearable and implantable microsystems for diagnostic and therapeutic use). This course explores the societal challenges that will be faced by our present engineering students during their careers and how microsystems can be used to address them. As a two credit-hour course, the class meets once per week in a two hour session; the basic format is an hour-long (invited) seminar presentation followed by an hour of questions and discussion. Seminar speakers have included former astronauts, experts on transportation and global warming, and industrial and governmental leaders in the area of health care. Topics have included clean air, clean water, homeland security, manufacturing, global warming, population growth and its implications, nanotechnology, space exploration, and medical implants, as well as engineering ethics. Students have regular homework assignments and select a topic of interest to them on which to do a term report. These oral reports have been very successful in allowing fascinating looks at many additional topics. In addition to societal challenges, the course also offers the opportunity to examine pioneers in electronics, from Benjamin Franklin to Robert Noyce, to obtain insight into the origins of innovation and the challenges faced in the past. Figure 8 and caption provide a glimpse of the course integration of societal challenges. The designated textbook is *Engineering Tomorrow*[8]. The course is available over the worldwide web.

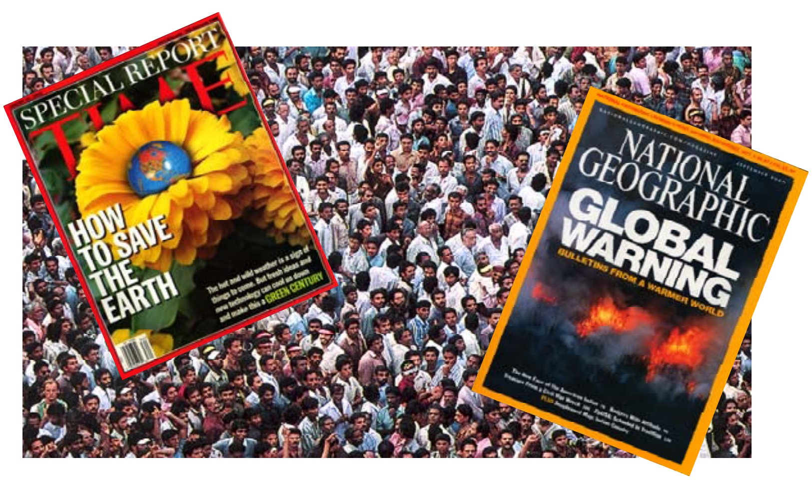


Figure 8. The *Societal Impact of Microsystems* course examines coming societal challenges and ways that microsystems will help address them. The course includes a component of engineering ethics, explores the origins of innovation, and considers the pioneering developments that have led us to where we are

Distance Education Dissemination (and Local Instructors)

At the education retreat, it was decided that distance education dissemination would be the expected delivery mechanism for each core course, and that elective courses would be identified (or developed) that used distance education methods. The core courses originate at UM. How could students at MSU, MTU, and industry be served well? It was decided that local instructors would be available at MSU and MTU for several purposes: provide face-to-face office hours, grade homework, administer and grade exams, and assign grades to students at that university. Each university was encouraged to obtain course approvals with course numbers at their university, and to assign credit hours consistent for their university; course approvals and local numbers were obtained at Michigan State University and Michigan Technological University. University term calendars are different. The student tuition payment is to his/her university, and there is no financial sharing of tuition funds. Costs to disseminate by distance education are borne by the originating university.

EECS 414 and EECS 830 use a high-quality high-cost dissemination of its course materials. Video is captured by a trained camera operator in a classroom studio with excellent lighting and sound capture facilities. The course materials and streaming video are posted to the class web site about one hour after the "live" class session. EECS 514 and 515 use a more cost-effective dissemination process; video is captured by a WIMS staff operating a camera; the course materials and streaming video are posted to a university web site usually within a day after the "live" class session. Methods are being explored to port a laboratory based course (EECS 425).

Course Enrollments

Enrollment in all the courses have been consistently strong. Except for the societal impact seminar course, each course is offered once per year, thereby necessitating a renewed student population each year. EECS 414 is a door-opener course, one that permits many students to get a glimpse of the MEMS and Microsystems area. Its enrollment numbers have ranged from 57 to 104 students at UM, plus about 50 students total at all USA distance education remote sites. The undergraduate-to-graduate student ratio is now about 2:1, different from the first years of the course that had about a 1:2 ratio. EECS 425 is likewise a pseudo-door opener course, attractive because of its MEMS/Microsystems content and its ABET satisfying major design experience. EECS 425 enrollment is limited by laboratory space capability. Table 2 has enrollment history since the inception of the MEMS and Microsystems curriculum. For each course, two numbers are provided: the first number is the enrollment of local students at the originating university; the second number is the enrollment of distance education students (remote students, industry professionals, etc). A table similar to Table 1 has been prepared for each core course, though not included in this paper for space considerations. The core courses have been received exceptionally well as evidenced by student course evaluation scores at UM; the rating scores for both course and teacher are among the best for undergraduate and graduate courses in the EECS Department at UM. Evaluations at MSU and MTU each use a different set of questions. Course evaluations by distance education students use yet another evaluation instrument. At UM, each undergraduate course has been mapped to a subset of 14 degree program outcomes (as done for ABET criteria). EECS 414 addresses 9 of the 14 program outcomes. Depending on the term, EECS 425 has addressed 10 or 11 of the 14 program outcomes.

Table 2. Enrollment History for MEMS/Microsystems Courses						
Enrollments are listed in format: Local Univ. Enrollment + Distance Education Enrollment **Bold** numbers are first time course was offered in MEMS/Microsystems curriculum Blank Cell = Course had not been created, or Not Offered EECS 425 was an *Integrated Circuits Laboratory* 3-credits course until 2001; EECS 425 is an Integrated Microsystems design 4-credits course starting in 2002. Courses are offered every year, except EECS 830 is offered every two years						
Acad.Yr.➔	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006
EECS 414		**57 + 25**	66 + 23	104 + 45	77 + 50	83 + 51
EECS 425	13 + NA	**26 + 16**	31 + 16	42 + 7	39 + 5	48 + 13
EECS 514			**30 + 6**	16 + 6	25 + 18	29 + 13
EECS 515				**17 + 2**	14 + 3	10 + 4
EECS 830			**21 + 10**		18 + 5	

Master of Engineering in Integrated Microsystems Degree Program

Also, at the education retreat, a Master of Engineering in Integrated Microsystems degree program was designed as a new degree to specifically address the cross-disciplinary needs of this field. The degree program accommodates students and industry professionals with a wide variety of backgrounds in engineering, basic sciences, and industry manufacturing and management. Degree approval was secured at UM in 2002. MTU already had a generic Master of Engineering degree program.

Table 3 highlights the degree requirements that include the core courses, technical electives, breadth electives, and an industry-oriented team project. Existence of the core courses led to establishment of the degree program. The technical electives include courses in fabrication technology, integrated circuits, RF MEMS and wireless communication, optical MEMS, microfluidics, bioMEMS, and environmental sensing. The breadth electives are industry-relevant courses that include manufacturing, management, quality engineering, and financial analysis courses. A very important aspect of the degree is its requirement for a team project with technical industrial involvement, along with the student and a university faculty member. The team project is a very effective way to increase interactions to expose students to real-world applications and problems. All the required courses and several electives are available remotely, making this degree completely available to distance education students over the web.

Table 3. Master of Engineering in Integrated Microsystems Degree Requirements	
30 Credit Hours	Total Credit Hours
12 Credit Hours	Credit Hours of Technical Depth Coursework: EECS 414, EECS 514, and EECS 515
6 to 8 Credit Hours	Credit Hours of Related Technical Breadth Coursework
5 to 8 Credit Hours	Coursework in Management, Product Development, Manufacturing Processes, Economic Factors, EECS 830
4 to 6 Credit Hours	Design Team Project w/ Industry Partner and/or Internship

Some Implications

The significance of this curriculum development initiative includes numerous factors. First is a coordinated set of comprehensive MEMS and Microsystems courses and educational resources that are readily shared internationally. The course materials are generously shared, either as a delivered course via distance education, or as a transfer of course materials to faculty who decide to teach the course locally at their university. A second factor is the progressive educational and learning continuum for students with clearly identified links between the courses. Several renowned faculty contributed to development of the courses and course materials. Another factor was the tremendous cooperation and goodwill among faculty at the initial three-partner State of Michigan universities (MSU, MTU, UM).

Building upon the MEMS/Microsystems core courses curriculum, other new related courses that have been offered include *Integrated Analog/Digital Interface Circuits* (EECS 511), *RF Wireless MEMS* (EECS 598A), *BioMEMS Through the Developing Organism* (EECS 598B), and *Micromanufacturing Processes* (MTU MEEM 4640/5640). Also, the existence of the core courses has led to the inclusion of MEMS and microsystem topics in other courses as well, from sophomore year to the advanced graduate level.

At Michigan Tech, a course *Micromanufacturing Processes* (MTU MEEM 4640/5640) is a technical elective from a mechanical engineering perspective, developing a broader perspective to students in the program. Course topics include: Scaling analysis, micrometrology methods and instruments, precision measurements and practices, lithographic processes, diamond machining, micromilling, microdrilling, micro EDM (electrical discharge machining), and analytical modeling of processes and normal practices.

Closing Summary

The Engineering Research Center for Wireless Integrated MicroSystems (WIMS ERC) has developed five core courses (Figure 1) that provide a broad comprehensive curriculum in MEMS and microsystems. Upper-level undergraduate students, graduate students, and industry professionals from engineering (electrical, computer, mechanical, biomedical, chemical, aerospace) and science (physics, chemistry, applied physics) have enrolled in the courses. Additional new technical and breadth elective courses have grown out of the core. Students are able to complete a master degree locally on campus or via distance education web online technology. Course enrollments have been consistently strong. Other universities, nationally and internationally, have used the courses in whole, or used course materials to further their own course offerings.

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List of Acronyms

ABET	Accreditation Board for Engineering and Technology
ANSYS	Software Package for MEMS Simulations (see EECS 414, 514, 515)
CAD	Computer Aided Design
CMOS	Complementary-Symmetry Metal Oxide Semiconductor Process (see EECS 425)
E/D	Enhancement/Depletion Circuit Structure (see EECS 425)
EECS	Electrical Engineering and Computer Science
ERC	Engineering Research Center
LOCOS	Local Oxidation of Silicon (see EECS 425)
ME	Mechanical Engineering
MEEM	Mechanical Engineering and Engineering Mechanics
MEMS	Microelectromechanical Systems
MSU	Michigan State University
MTU	Michigan Technological University
NSF	National Science Foundation
UM	University of Michigan
USA	United States of America (see Table 1)
WIMS	Wireless Integrated MicroSystems