

Principles of MEMS Transducers

EEL 5225

Class Periods: Tuesday, Period 7 (1:55 to 2:45 pm), Thursday Period 7-8 (1:55 to 3:50 pm)

Location: Black Hall , Room 415

Academic Term: Fall 2019

Instructor:

Jack Judy

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382-846-1275

Office Hours: Tuesday, Period 8 (2:55 to 3:50 pm), Location: 210 NRF

Teaching Assistant/Peer Mentor/Supervised Teaching Student:

Please contact through the Canvas website

- None

Course Description

(3 credits): This course provides an introduction to the principles of micro-electro-mechanical-systems design and operation. The physics of transduction mechanisms and the engineering used to produce well-design transducers (i.e., microsensors and microactuators).

Course Pre-Requisites / Co-Requisites

Differential and integral calculus, introductory statics and dynamics, introductory circuit theory, semiconductor theory (e.g., EEL 3396), introductory microfabrication (e.g., EEL4331), or with permission of the instructor.

Course Objectives

To introduce MEMS transducers through exploration of sensing/ actuation mechanisms, materials, and microfabrication technologies and to model multi-energy-domain systems using lumped-element models.

Materials and Supply Fees

None.

Required Textbooks and Software

1. Textbook
 - a. M. Madou, *Fundamentals of Microfabrication and Nanotechnology, Third Edition, Volume Two: Manufacturing Techniques for Microfabrication and Nanotechnology*, CRC Press, 2011.
2. Readings:
 - a. to be handed out in class.
3. Software:
 - a. Matlab with Simulink Student Edition
 - b. Excel
 - c. or similar numerical computation software

Recommended Materials

1. Books:
 - a. R.C. Jaeger, *Introduction to Microelectronic Fabrication*, Prentice Hall, 2002.
 - b. S. A. Campbell, *Fabrication Engineering at the Micro- and Nanoscale 4th Edition*, Oxford University Press, 2012.
 - c. S. Wolf and R.N. Tauber, *Silicon Processing for the VLSI Era, Volume 1 – Process Technology, 2nd Edition*, 2000.
 - d. J. D. Plummer, et al., *Silicon VLSI Technology: Fundamentals, Practice, and Modeling*, Pearson, 2000.
 - e. G. Kovacs, *Micromachined Transducers Sourcebook*, McGraw-Hill, 1998
 - f. N. Maluf, *An Introduction to Microelectromechanical Systems Engineering*, Artech House, 2000.

- g. S. Senturia, *Microsystem Design, 2nd Edition*, Kluwer Academic Publishers, 2004
- 2. Primary Journals:
 - a. J. Microelectromechanical Systems (IEEE/ASME)
 - b. J. Micromechanics and Microengineering (IoP)
 - c. Sensors and Actuators (Elsevier)
 - d. IEEE Sensors Journal (IEEE)

Course Schedule

- 1. **Introduction and Orientation**
 - a. **Overview of MEMS**
 - b. **Transducer Basics**
 - c. **Scaling Laws**
- 2. **MEMS Fabrication Technology**
 - a. **Micromanufacturing:**
 - i. contamination, cleaning, yield, economics, design of experiments (DOE)
 - b. **Core Micromachining Processes:**
 - i. photolithography, layout, deposition, etching, surface micromachining, etc.
 - c. **MEMS-Specific Advanced Fabrication Processes:**
 - i. wafer bonding, DRIE, anisotropic wet etching, laser machining, XeF₂, CO₂ super critical release, atomic layer deposition (ALD), electroplating, anodization, chemical-mechanical polishing (CMP), etc.
 - d. **MEMS Process Integration:**
 - i. combining process modules to fabricate a given design
 - e. **MEMS Metrology:**
 - i. material properties, test structures, thin-film stress
 - f. **MEMS Packaging:**
 - i. dicing, wafer-scale, assembly, stresses, hermeticity

Attendance Policy, Class Expectations, and Make-Up Policy

Attendance is required. Notify instructor of unavoidable planned absences so that arrangements can be made to capture content and turn in due assignments. Cell phone use in class is forbidden except for urgent matters. However, use of a table or laptop is allowed when viewing lecture notes and other class materials. Late homework receives penalty (reduction in maximum possible score). Exams can be made up under extreme circumstances and requires instructor prior approval.

Evaluation of Grades

Assignment	Total Points	Percentage of Final Grade
Homework Sets	~100 each	25%
Midterms/Quizzes	~100 each	30%
Mini-Projects	~100 each	15%
Final Exam	~100 each	30%
Total		100%

More information on UF grading policy may be found at:

<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades>

Students Requiring Accommodations

Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, <https://www.dso.ufl.edu/drc>) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Course Evaluation

Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at <https://evaluations.ufl.edu/evals>. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at <https://evaluations.ufl.edu/results/>.

University Honesty Policy

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Honor Code (<https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Cynthia Blunt-Turner, ECE Graduate Program Coordinator, 392-4945, cturner@ece.ufl.edu
- Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

Campus Resources:

Health and Wellness

U Matter, We Care:

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: <http://www.counseling.ufl.edu/cwc>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the [Office of Title IX Compliance](#), located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)

Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

Academic Resources

E-learning technical support, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu.
<https://lss.at.ufl.edu/help.shtml>.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. <https://www.crc.ufl.edu/>.

Library Support, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.
<https://teachingcenter.ufl.edu/>.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers.
<https://writing.ufl.edu/writing-studio/>.

Student Complaints Campus: https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf.

On-Line Students Complaints: <http://www.distance.ufl.edu/student-complaint-process>.