

EEL 5225

Principles of MEMS Transducers

Fall 2017

1. **Catalog 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).
2. **Pre-requisites: Pre-requisites:** Differential and integral calculus, introductory statics and dynamics, introductory circuit theory, semiconductor theory (e.g., EEL 3396), introductory microfabrication (e.g., EEE4331), or with permission of the instructor.
3. **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.
4. **ABET (Professional):** N/A
5. **ABET (Outcomes):** N/A
6. **Instructor:** Dr. Jack Judy
 - a. Office location: 210 NRF
 - b. Telephone: Office: 352-846-1275 and Cell: 352-672-1787 (SMS message first)
 - c. E-mail address: jack.judy@ufl.edu
 - d. Class Web site: UF e-Learning
 - e. Office hours: Tuesday at 4:00 pm (after Thursday's lecture)
7. **Teaching Assistant:** N/A
8. **Meeting Times & Location:**
 Larsen 239, Tuesday 1:55-2:45 pm, Thursday 1:55-3:50 pm
Final Exam: Wednesday, December 11th, **7:30 am – 9:30 am** (Location: Larsen 239)
9. **Class/Laboratory Schedule:** N/A
10. **Material and Supply Fees:** None.
11. **Textbooks and Software Required:** Free e-book access at UF Library
 - a. Readings to be handed out in class.
 - b. Software:
 - i. Matlab with Simulink Student Edition
 - ii. Excel
 - iii. or similar numerical computation software

12. **Recommended Reading:** Supplemental material to be assigned and provided via course website

- a. Books:
 - i. R.C. Jaeger, *Introduction to Microelectronic Fabrication*, Prentice Hall, 2002.
 - ii. M. Madou, *Fundamentals of Microfabrication*, 2nd Ed., CRC Press, 2002.
 - iii. S. Wolf and R.N. Tauber, *Silicon Processing for the VLSI Era, Volume 1 – Process Technology, 2nd Edition*, 2000.
 - iv. S. Senturia, *Microsystem Design, 2nd Edition*, Kluwer Academic Publishers, 2004
 - v. N. Maluf, *An Introduction to Microelectromechanical Systems Engineering*, Artech House, 2000.
 - vi. J. A. Pelesko and D. H. Bernstein, *Modeling of MEMS and NEMS*, Chapman & Hall/CRC, 2003.
 - vii. G. Kovacs, *Micromachined Transducers Sourcebook*, McGraw-Hill, 1998
 - viii. W. Trimmer, Editor, *Micromechanics and MEMS*, IEEE Press, 1997
- b. Primary Journals:
 - i. J. Microelectromechanical Systems (IEEE/ASME)
 - ii. J. Micromechanics and Microengineering (IoP)
 - iii. Sensors and Actuators (Elsevier)
 - iv. IEEE Sensors Journal (IEEE)

13. **Course Outline:**

- a. Introduction and Orientation
 - i. Overview of MEMS
 - ii. Transducer Basics
 - iii. Scaling Laws
- b. Fabrication Technology
 - i. **Micromanufacturing:** contamination, cleaning, yield, economics, design of experiments (DOE)
 - ii. **Core Micromachining Processes:** photolithography, layout, deposition, etching, surface micromachining, etc.
 - iii. **Advanced and MEMS-Specific Fabrication Processes:** wafer bonding, DRIE, anisotropic wet etching, laser machining, XeF₂, CO₂ super critical release, atomic layer deposition (ALD), electroplating, anodization, chemical-mechanical polishing (CMP), etc.
 - iv. **Process Integration:** combining process modules to fabricate a given design
 - v. **MEMS Metrology:** material properties, test structures, thin-film stress
 - vi. **Packaging:** dicing, wafer-scale, assembly, stresses, hermeticity
- c. Device-Level and System-Level Transducer Considerations
 - i. Transduction Mechanisms
 - ii. Introduction to lumped-element modeling (LEM)
 - iii. Interface electronics
 - iv. Noise, stability, reliability

- d. **Attendance and Expectations:** Attendance is required for all lectures unless otherwise noted by a course website announcement. Cell phones and other electronic devices are to be silenced. No text messaging during class or exams.

Students may ask each other questions and support one another, but all homework submitted must be each student's own individual work.

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies that can be found in the online catalog at: <https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx>

14. Grading:

- a. Homework: 25%
- b. Midterms/Quizzes: 30%
- c. Mini-Projects: 15%
- d. Final Exam: 30% (Dec 13, 10:00 – 12:00, Location: same as lectures)

15. Grading Scale:

A	A-	B+	B	B-	C+	C	C-	D+	D	D-	E
92 >	90-91	87-89	83-86	80-82	77-79	73-76	70-72	67-69	63-66	60-62	< 60

A C- will not be a qualifying grade for critical tracking courses. In order to graduate, students must have an overall GPA and an upper-division GPA of 2.0 or better (C or better).” Note: a C- average is equivalent to a GPA of 1.67, and therefore, it does not satisfy this graduation requirement. For more information on grades and grading policies, please visit: <https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>

16. **Homework and Make-Up Exam Policy:** Late homework will receive a 20% deducted per day unless prior arrangements were made with the instructor.

If you have a University-approved excuse and arrange for it in advance, or in case of documented emergency, a make-up exam will be allowed and arrangements can be made for making up missed work. University attendance policies can be found at: <https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx>

Otherwise, make-up exams will be considered only in extraordinary cases, and must be taken before the scheduled exam. The student must submit a written petition to the instructor two weeks prior to the scheduled exam and the instructor must approve the petition.

17. **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 (<http://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.
18. **Accommodation for Students with Disabilities:** Students requesting classroom accommodation must first register with the Dean of Students Office. That office will provide documentation to the student who must then provide this documentation to the course instructor when requesting accommodation.
19. **UF Counseling Services:** Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:
- UF Counseling & Wellness Center, psychological and psychiatric services, 3190 Radio Rd, 392-1575, online: <http://www.counseling.ufl.edu/cwc/Default.aspx>,
 - Career Resource Center, Reitz Union, career and job search services, 392-1601.
 - University Police Department, 392-1111 or 911 for emergencies
20. **Software Use:** All faculty, staff and student 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.
21. **Course Evaluation:** Students are expected to provide feedback on the quality of instruction in this course based on 10 criteria. These evaluations are conducted online at: <https://evaluations.ufl.edu>. 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>.