

Principles of MEMS
EEL 5225 Class# 28955
Class Periods: MWF 3 (9:35am – 10:25am)
Location: LAR 239
Academic Term: Spring 2023

Instructor:

David Arnold

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LAR 213

Office Hours (online): TBD

Course Description

Introduction to principles of micro-electro-mechanical devices and systems. Credits: 3

Course Pre-Requisites / Co-Requisites

Basic semiconductor theory (EEL 3008), differential and integral calculus, introductory circuit theory, signals/systems or vibrations, semiconductor fabrication (preferred)

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

Stephen D. Senturia, *Microsystem Design*, Kluwer Academic Publishers: Boston, 2001.

MATLAB, MathCAD, Python, Excel, or equivalent may be needed for homework.

Recommended Materials

Supplemental materials provided on Canvas.

Supplemental Books:

G. Kovacs, *Micromachined Transducers Sourcebook*, McGraw-Hill, 1998

M. Madou, *Fundamentals of Microfabrication*, 2nd Ed., CRC Press, 2002.

R.C. Jaeger, *Introduction to Microelectronic Fabrication*, 2nd ed., Prentice Hall, 2002.

J. A. Pelesko and D. H. Bernstein, *Modeling of MEMS and NEMS*, Chapman & Hall/CRC, 2003.

T. B. Jones and N. G. Nenadic, *Electromechanics and MEMS*, Cambridge University Press, 2013.

Course Schedule (subject to change)

Week	Topic	Due Dates (estimated)	
1	Course Overview, Intro to MEMS, Transducer Basics		Quiz 1
2	Transducers, Materials, Thermal Oxidation	HW1	
3	Oxidation, PVD, CVD		
4	Lithography, Etching, Implantation	HW2	
5	Diffusion, Process Flows	HW3	

6	Surface Micromachining, LIGA		Quiz 2
7	Bulk Micromachining, Wafer Bonding, Devices, Packaging		
8	Intro to Lumped Element Modeling, One-Port Devices	HW4	
9	Nonlinear & Distributed Devices		
10	Element Connections, Two-Port Devices	HW5	
11	Dynamics, Transducer Modeling,		Quiz 3
12	Electrodynamic, Piezoelectric	HW6	
13	Electrostatic, Non-conservative Transducers		
14	Mechanics	HW7	
15	Thermal	HW8	

Online Course Recording

Our class sessions may be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.

Attendance Policy, Class Expectations, and Make-Up Policy

Live attendance of Zoom broadcasts is required. Zoom requires a webcam and stable internet connection. During live zoom meetings, I prefer that students keep their camera on during the class so that I can see you as I would during normal face-to-face classes. Studies show that if we can see each other's faces then we will have more engagement, more student success, and more faculty success. However, this is not a requirement. I understand if on certain days you can't have your camera on due to internet bandwidth limitations, other family members, health issues, or any other reasons.

Excused absences must be consistent with university policies in the undergraduate catalog (<https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx>) and require appropriate documentation.

Evaluation of Grades

Assignment	Percentage of Final Grade
Homework (~9)	20%
Mini-Project	15%
Quizzes (3)	45%
Final Exam	30%
TOTAL	100%

Grading Policies

Grading Scale

Numeric Cutoff	Letter Grade	Grade Points
90.00	A	4.00

86.67	A-	3.67
83.33	B+	3.33
80.00	B	3.00
76.67	B-	2.67
73.33	C+	2.33
70.00	C	2.00
66.67	C-	1.67
63.33	D+	1.33
60.00	D	1.00
56.67	D-	0.67
<56.67	E	0.0

Late Submission Policy

All assignments are due at 11:59 pm on the due date. A deduction of -20% if submitted within 24 hr, and -40% if submitted within 48 hr. Zero credit after 48 hr late.

More information on UF grading policy may be found at:

<https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>

Students Requiring Accommodations

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>.

In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript

of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

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://sccr.dso.ufl.edu/process/student-conduct-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. *****CHEATING, COPYING, or PLAGERISM will result in a ZERO ON THE ASSIGNMENT, and DISCIPLINARY ACTION WILL BE PURSUED**

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:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennacc@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: <https://counseling.ufl.edu>, 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 Connections Center, Reitz Union, 392-1601. Career assistance and counseling; <https://career.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://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>; <https://care.dso.ufl.edu>.

On-Line Students Complaints: <https://distance.ufl.edu/state-authorization-status/#student-complaint>.