

MENG 5314 – Micro Electromechanical Systems (MEMS)

Course Syllabus

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|---|---|--------------------|------------|---------------------|------------|------------------------|------------|-----------------------------|------------|-------------------|------------|
| Semester / Year | Spring / 2022 | | | | | | | | | | |
| Catalog Description | This course introduces the students to principles, modeling, interfacing, and signal conditioning of micro-electro-mechanical systems (MEMS) such as motion sensors and actuators. It also covers basic electronic devices, MEMS resonators, embedded microprocessor systems and control, power transfer components, and mechanism design. The course provides knowledge in the analysis and design of hardware-in-the-loop through simulation and rapid prototyping of real-time closed-loop computer control of electromechanical systems. | | | | | | | | | | |
| Prerequisites | ENGR 2302 Dynamics, MATH 3305 or Graduate student standing | | | | | | | | | | |
| Instructor name | Dr. A. Ibrahim | | | | | | | | | | |
| Contact info | Email: aibrahim@uttyler.edu Office: RBN 3008 | | | | | | | | | | |
| Class Type / Location | Hybrid-Synchronized-Zoom | | | | | | | | | | |
| Class Time | Wednesday 5:30 pm – 8:15 pm | | | | | | | | | | |
| Office Hours | MW 8:30 am -10:00 am | | | | | | | | | | |
| Credits | 3 credits | | | | | | | | | | |
| Required Textbook | MEMS Linear and Nonlinear Statics and Dynamics, Younis, Mohammad I., Springer, New York, 2011. | | | | | | | | | | |
| Additional requirements | Programming skills with MATLAB or Mathematica is a Must. | | | | | | | | | | |
| Evaluation Method | <table> <tr> <td>Assignments</td> <td>30%</td> </tr> <tr> <td>Midterm Exam</td> <td>15%</td> </tr> <tr> <td>Project Article</td> <td>20%</td> </tr> <tr> <td>Project Presentation</td> <td>10%</td> </tr> <tr> <td>Final Exam</td> <td>25%</td> </tr> </table> | Assignments | 30% | Midterm Exam | 15% | Project Article | 20% | Project Presentation | 10% | Final Exam | 25% |
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| Midterm Exam | 15% | | | | | | | | | | |
| Project Article | 20% | | | | | | | | | | |
| Project Presentation | 10% | | | | | | | | | | |
| Final Exam | 25% | | | | | | | | | | |
| Grading Policy / Scale | Letter grades: 90-100: A, 80-89: B, 70-79: C, 60-69:D, 0-59: F | | | | | | | | | | |
| Important events / dates | Exam date: As per the schedule released by the University | | | | | | | | | | |
| Attendance / Makeup | Attendance is required / No makeup | | | | | | | | | | |
| Course Learning Objectives / ABET & PEOs relation | <p>By the end of this course, the student should be able to:</p> <ol style="list-style-type: none"> 1. Describe MEMS and their related design components. 2. Analyze nonlinear dynamic responses of MEMS devices. 3. Design MEMS resonators and analyze their static and dynamic behaviors. 4. Apply analytical and numerical techniques to model and simulate MEMS, considering nonlinear multi-physics interaction and actuation forces. 5. Conduct a major project leading to a draft of a publishable level paper. | | | | | | | | | | |
| Tentative Topics | <ol style="list-style-type: none"> 1. Introduction to MEMS and their modeling challenges laws of motion. 2. Sensing and Actuation in MEMS. 3. Elements of Lumped-Parameter Modeling in MEMS. 4. Introduction to Nonlinear Dynamics. 5. Continuous Systems: Microbeams. | | | | | | | | | | |

Assignments:

- All assignments must be submitted as a single scanned file in pdf format on the due date.
Phone pictures will not be accepted.
- Late HWs **will not be accepted**, and a **Zero** grade will be offered.

Course Project:

- Projects will be done **individually or with collaborations of two students**. For collaborative projects, the instructor will distribute the students.
- The project's topic should be investigating the static and dynamic behavior of an Energy harvester device of the **instructor's choice**. However, any idea or suggested project from the student will be welcome after the instructor's approval. It can also be a new idea of a MEMS device of improved performance or desired characteristics.
- The final report should be written in **overleaf** (<https://www.overleaf.com/>) in a research article format (10-15 pages).
- You must create an account on **overleaf** using your **UT-Tyler credentials**. Later, the instructor will share an Overleaf project template.
 - Follow the following link for overleaf tutorials:
([https://www.overleaf.com/learn/latex/LaTeX_video_tutorial_for_beginners_\(video_1\)](https://www.overleaf.com/learn/latex/LaTeX_video_tutorial_for_beginners_(video_1)))
- The article should be written in your own words and following the ME writing report guide. The submitted article will be checked for plagiarism. Direct copying from any paper, web or other sources is prohibited and will result in a **Zero grade**.
- The final research article (10-15 pages) is **due before the last week of the semester**.
- The report should be written in a Journal paper format. It shall include:
 - **literature summary** about the topic,
 - **Mathematical model**,
 - **Simulation results** and comparisons with literature results,
 - **Experimental results**, if applicable,
 - **Discussion**,
 - **Summary and conclusions**
 - **Recommendations** (research ideas) for future works.
 - **Please refer to the project guidelines on page 4.**
- Students **will present their projects in the last week** of the classes.
 - **Please refer to the presentation guidelines on page 5.**
- All **codes** used for generating the reported results **should be submitted** with the final article.

Outline

1-Introduction to MEMS and Their Modeling Challenges

2-Refresher on Linear Vibrations

- Free Vibration of Single-Degree-of-Freedom Systems
- Forced Harmonic Excitation of Single-Degree-of-Freedom Systems
- Vibrating MEMS Gyroscopes
- Base Excitations of SDOF Systems and Accelerometers Principles
- Vibrations of Two-Degree-of-Freedom Systems
- Numerical Integration
- MEMS Band-Pass Filters

3- Sensing and Actuation in MEMS

- Electrothermal Actuation
- Piezoelectric Actuation and Detection
- Electromagnetic and Magnetic Actuation
- Piezoresistive Detection
- Electrostatic Actuation and Detection (simple parallel-plate, comb-drive, torsional mirrors)
- Resonant Sensors

4-Elements of Lumped-Parameter Modeling in MEMS

- Stiffness of Microstructures
- Spring-Mass Models
- Damping in MEMS (focus mainly on squeeze film damping and some gas fundamentals)

5-Introduction to Nonlinear Dynamics

- Nondimensionalization
- Fixed Points and Linearization
- Bifurcations of Fixed Points
- Phase Portraits
- Step-Input Actuation of Capacitive RF Switches
- Dynamics of Torsional Actuators and Micromirrors
- Nonlinear Oscillations

6-Continuous Systems: Microbeams

- Equation of Motion and Boundary Conditions
- Static Issues (residual stresses, non-ideal boundaries, buckling)
- Natural Frequencies and Mode Shapes
- Forced Vibration and Modal Analysis

| Project Guidelines* | | |
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| Week # | Task | Description |
| Week 1-3 | Conduct a literature review | <ul style="list-style-type: none"> • Read articles about Vibrations Energy Harvesting (understand the concept and working mechanism of Triboelectric and Piezoelectric EH) |
| Week 4-5 | Introduction writing | <ul style="list-style-type: none"> • The introduction requires a review of the literature about the research topic. • Construct it as a descriptive funnel, starting with broad topics and slowly focusing on the work at hand. • Perhaps three to four paragraphs are needed. Start with one paragraph introducing the reader to the general field of study. The subsequent paragraphs then describe how an aspect of this field could be improved. • The final paragraph is critical. It clearly states, most likely in the paragraph's first sentence, that the present study will answer an experimental question. The hypothesis is then stated. • Next, briefly describe the approach that was taken to test the hypothesis. Finally, a summary sentence may be added stating how the answer of your question will contribute to the overall field of study. |
| Week 6-7 | Methods, Setup, Model description | <ul style="list-style-type: none"> • Describe the key procedure and technique used in the study. Keep explanations brief and concise. • If a specific experimental design is utilized, describe this design in the second section of this part. • Similarly, if a theoretical or modeling component is utilized, it should also be incorporated in the Methods' initial portion. |
| Week 8-10 | Results and Discussion | <ul style="list-style-type: none"> • The Results section presents the experimental/Simulated data to the reader. • The data should be presented in tables and figures. Introduce each group of tables and figures in a separate paragraph where the overall trends and data points of particular interest are noted. You may want to indicate the placement of a specific table or figure in the text. • Note that each table and figure in the paper must be referred to in the Results section. • Use the results that address your objectives to describe and summarize the most important findings. • identify the most interesting, significant, remarkable findings that were presented in the results • Example of expected results <ul style="list-style-type: none"> - Resonance Frequency, - Finding the Optimal resistance, - Frequency – Voltage/Power Curves. |
| Week 11 | Conclusions | <ul style="list-style-type: none"> • Again, first, introduce the work and then briefly state the major results. |

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| | | <ul style="list-style-type: none"> • Then state the major points of the discussion. • Finally, end with a statement of how this work contributes to the overall field of study. |
| Week 12 | Abstract | <ul style="list-style-type: none"> • The abstract should be considered as an independent document. • The first sentence should clearly state the objective of the work. • The subsequent sentences describe how the investigation was carried out. • The following sentences describe the work results with as much precision as possible without being verbose. • The final sentences describe the significance of the results and the impact of this work on the general field of study. |
| Week 13-14 | Review | <ul style="list-style-type: none"> • Review the whole manuscript with proofreading and check everything for final submission. |
| Week 15 | Submission & Presentation | <ul style="list-style-type: none"> • Submit your project in PDF format. • Share access to final overleaf. • Present your article in the class. |

* For more guidelines about report writing, please refer to the Report Writing Guide posted on Canvas.

| PowerPoint Presentation Guidelines | | |
|---|--------------------|---|
| Section | # of Slides | Description |
| General Rules | - | <ul style="list-style-type: none"> • Follow the 5/5/5 rule: no more than five words per line of text, five lines of text per slide, or five text-heavy slides in a row. • Choose readable colors and fonts. • Don't overload your presentation with animations. |
| Title slide | 1 | <ul style="list-style-type: none"> • Title of the talk (probably the same as your paper), the names of all group members, the class and university names, and the date the talk is given. |
| Outline slide | 1 | <ul style="list-style-type: none"> • List the headings of what you are presenting. |
| Introduction and Motivation | 3 - 4 | <ul style="list-style-type: none"> • Explain why your work is impressive. • Place the study in context – how does it relate to / follow from the scientific literature on this subject. If it relates to • Use some pretty visuals (photographs, drawings, etc.) to get the audience excited about the issue and questions you are addressing. |
| Methods, Setup, Model description | 3 - 5 | <ul style="list-style-type: none"> • Summarize the design. Show a picture of your organisms and justify why they are appropriate for addressing the questions you are addressing. • Show a picture of your lab setup and/or a model. • Show a diorama of your experimental design (with sample sizes, number of replicates, sampling frequency, etc.). • Mention what parameters you measured, but do not detail the exact procedures used. |
| Results and Discussion | 4-6 | <ul style="list-style-type: none"> • Show a photograph (or sketch) that shows an interesting qualitative results. |

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| | | <ul style="list-style-type: none"> • Then display the results in graphical form, reminding the audience of your hypothesis and stating whether it was supported as you do so. • Use simple, clean, clearly labeled graphs with proper axis labels. • Do not use light colors (yellow, light green, or pink) in your figures. They do not show up well when projected. |
| Conclusions | 1-2 | <ul style="list-style-type: none"> • Correctly interpret your results. • Constructively address sources of error and methodological difficulties. • Place your results in context and draw implications from them. |

| Course Schedule | | |
|------------------------|--------------|------------------------------|
| Week # | Date | Chapter** |
| Week 1 | 01/12 | Ch1/ Ch2 |
| Week 2 | 01/19 | Ch2 |
| Week 3 | 01/26 | Ch2 |
| Week 4 | 02/02 | Ch3 |
| Week 5 | 02/09 | Ch4 |
| Week 6 | 02/16 | Ch4 |
| Week 7 | 02/23 | Midterm Exam-Ch5 |
| Week 8 | 03/02 | Ch5 |
| Week 9 | 03/09 | Spring Brake |
| Week 10 | 03/16 | Ch5 |
| Week 11 | 03/23 | Ch5 |
| Week 12 | 03/30 | Ch6 |
| Week 13 | 04/06 | Ch6 |
| Week 14 | 04/13 | Ch6 |
| Week 15 | 04/20 | Report / Presentation |

** The materials listed in the table are the proposed materials, but the instructor has the right to change them based on the progress during the semester.

University Policies:

University, College, and Department Policies:

1. Modifications

The instructor reserves the right to change this syllabus partially or fully at any point in time. Sufficient time and notice will be provided to the class before the activation of the changes.

2. UT Tyler Honor Code

Every member of the UT Tyler community joins together to embrace: Honor and integrity that will not allow me to lie, cheat, or steal, nor to accept the actions of those who do.

3. Student Standards of Academic Conduct

Disciplinary proceedings may be initiated against any student who engages in scholastic dishonesty, including, but not limited to, cheating, plagiarism, collusion, the submission for credit of any work or materials that are attributable in whole or in part to another person, or material which has been submitted within a different course without the explicit approval of the instructor, taking an examination for another person, any act designed to give an unfair advantage to a student or the attempt to commit such acts.

- i. "Cheating" includes, but is not limited to:
 - copying from another student's test paper;
 - using, during a test, materials not authorized by the person giving the test;
 - failure to comply with instructions given by the person administering the test;
 - possession during a test of materials, or devices and instruments allowing access to materials, which are not authorized by the person giving the test, such as class notes or specifically designed "crib notes" as well as cell phones, to name a few. The presence of textbooks constitutes a violation if they have been specifically prohibited by the person administering the test;
 - using, buying, stealing, transporting, or soliciting in whole or part the contents of an unadministered test, test key, homework solution, or computer program;
 - collaborating with or seeking aid from another student or person during a test or other assignment without explicit authorization;
 - discussing the contents of an examination with another student who will take the examination;
 - divulging the contents of an examination, for the purpose of preserving questions for use by another, or removing material from the exam location, when the instructors has designated that the examination is not to be removed from the examination room or not to be returned or to be kept by the student;
 - substituting for another person, or permitting another person to substitute for oneself to take a course, a test, or any course-related assignment;
 - paying or offering money or other valuable thing to, or coercing another person to obtain an unadministered test, test key, homework solution, or computer program or information about an unadministered test, test key, home solution, or computer program;
 - falsifying research data, laboratory reports, and/or other academic work offered for credit;
 - taking, keeping, misplacing, or damaging the property of The University of Texas at Tyler, or of another, if the student knows or reasonably should know that an unfair academic advantage would be gained by such conduct; and
 - misrepresenting facts, including providing false grades or resumes, for the purpose of obtaining an academic or financial benefit or injuring another student academically or financially.
- ii. "Plagiarism" includes, but is not limited to, the appropriation, buying, receiving as a gift, or obtaining by any means another's work and the submission of it as one's own academic work offered for credit.

- iii. "Collusion" includes, but is not limited to, the unauthorized collaboration with another person in preparing academic assignments offered for credit or collaboration with another person to commit a violation of any section of the rules on scholastic dishonesty.
- iv. All written work that is submitted will be subject to review by plagiarism software.
- v. Penalty for any related infractions will be decided at the discretion of the instructor including, but not limited to, granting of a failing grade in part or the course or in the entire course.

4. Students Rights and Responsibilities

To know and understand the policies that affect your rights and responsibilities as a student at UT Tyler, please follow this link: <http://www.uttyler.edu/wellness/rightsresponsibilities.php>

5. Important Covid-19 Information for Classrooms and Laboratories

Students are required to wear face masks covering their nose and mouth, and follow social distancing guidelines, at all times in public settings (including classrooms and laboratories), as specified by [Procedures for Fall 2020 Return to Normal Operations](#). The UT Tyler community of Patriots views adoption of these practices consistent with its [Honor Code](#) and a sign of good citizenship and respectful care of fellow classmates, faculty, and staff.

Students who are feeling ill or experiencing symptoms such as sneezing, coughing, or a higher than normal temperature will be excused from class and should stay at home and may join the class remotely. Students who have difficulty adhering to the Covid-19 safety policies for health reasons are also encouraged to join the class remotely. Students needing additional accommodations may contact the Office of Student Accessibility and Resources at University Center 3150, or call (903) 566-7079 or email saroffice@uttyler.edu.

6. Recording of Class Sessions

Class sessions may be recorded by the instructor for use by students enrolled in this course. Recordings that contain personally identifiable information or other information subject to FERPA shall not be shared with individuals not enrolled in this course unless appropriate consent is obtained from all relevant students. Class recordings are reserved only for the use of students enrolled in the course and only for educational purposes. Course recordings should not be shared outside of the course in any form without express permission.

7. Campus Carry

We respect the right and privacy of students 21 and over who are duly licensed to carry concealed weapons in this class. License holders are expected to behave responsibly and keep a handgun secure and concealed. More information is available at <http://www.uttyler.edu/about/campus-carry/index.php>

8. UT Tyler a Tobacco-Free University

All forms of tobacco will not be permitted on the UT Tyler main campus, branch campuses, and any property owned by UT Tyler. This applies to all members of the University community, including students, faculty, staff, University affiliates, contractors, and visitors.

Forms of tobacco not permitted include cigarettes, cigars, pipes, water pipes (hookah), bidis, kreteks, electronic cigarettes, smokeless

tobacco, snuff, chewing tobacco, and all other tobacco products.

There are several cessation programs available to students looking to quit smoking, including counseling, quitlines, and group support.

For more information on cessation programs please visit www.uttyler.edu/tobacco-free.

9. Grade Replacement/Forgiveness and Census Date Policies

Students repeating a course for grade forgiveness (grade replacement) must file a Grade Replacement Contract with the Enrollment Services Center (ADM 230) on or before the Census Date of the semester in which the course will be repeated. Grade Replacement Contracts are available in the Enrollment Services Center or at <http://www.uttyler.edu/registrar>. Each semester's Census Date can be found on the Contract itself, on the Academic Calendar, or in the information pamphlets published each semester by the Office of the Registrar.

Failure to file a Grade Replacement Contract will result in both the original and repeated grade being used to calculate your overall grade point average. Undergraduates are eligible to exercise grade replacement for only three course repeats during their career at UT Tyler; graduates are eligible for two grade replacements. Full policy details are printed on each Grade Replacement Contract.

The Census Date is the deadline for many forms and enrollment actions of which students need to be aware. These include:

- Submitting Grade Replacement Contracts, Transient Forms, requests to withhold directory information, approvals for taking courses as Audit, Pass/Fail or Credit/No Credit.
- Receiving 100% refunds for partial withdrawals. (There is no refund for these after the Census Date)
- Schedule adjustments (section changes, adding a new class, dropping without a "W" grade)
- Being reinstated or re-enrolled in classes after being dropped for non-payment
- Completing the process for tuition exemptions or waivers through Financial Aid

10. State-Mandated Course Drop Policy

Texas law prohibits a student who began college for the first time in Fall 2007 or thereafter from dropping more than six courses during their entire undergraduate career. This includes courses dropped at another 2-year or 4-year Texas public college or University. For purposes of this rule, a dropped course is any course that is dropped after the census date (See Academic Calendar for the specific date).

Exceptions to the 6-drop rule may be found in the catalog. Petitions for exemptions must be submitted to the Enrollment Services Center and must be accompanied by documentation of the extenuating circumstance. Please contact the Enrollment Services Center if you have any questions.

11. Disability/Accessibility Services

In accordance with Section 504 of the Rehabilitation Act, Americans with Disabilities Act (ADA) and the ADA Amendments Act (ADAAA) the University of Texas at Tyler offers accommodations to students with learning, physical and/or psychological disabilities. If you have a disability, including a non-visible diagnosis such as a learning disorder, chronic illness, TBI, PTSD, ADHD, or you have a history of modifications or accommodations in a previous educational environment, you are encouraged to visit <https://hood.accessiblelearning.com/UTTyler> and fill out the New Student application. The Student Accessibility and Resources (SAR) office will contact you when your application has been submitted and an appointment with Cynthia Lowery, Assistant Director of Student Services/ADA Coordinator. For more information, including filling out an application for services, please visit the SAR webpage at <http://www.uttyler.edu/disabilityservices>, the SAR office located in the University Center, # 3150 or call 903.566.7079.

The University of Texas at Tyler has a continuing commitment to providing reasonable accommodations for students with documented disabilities. Like so many things this Fall, the need for accommodations and the process for arranging them may be altered by the COVID-19 changes we are experiencing and the safety protocols currently in place. Students with disabilities who may need accommodation(s) in order to fully participate in this class are urged to contact the Student Accessibility and Resources Office (SAR) as soon as possible, to explore what arrangements need to be made to ensure access. During the Fall 2020 semester, SAR will be conducting all appointments via ZOOM. If you have a disability, you are encouraged to visit <https://hood.accessiblelearning.com/UTTyler> and fill out the New Student Application. For more information, please visit the SAR webpage at <http://www.uttyler.edu/disabilityservices> or call 903.566.7079.

Student Absence due to Religious Observance

Students who anticipate being absent from class due to a religious observance are requested to inform the instructor of such absences by the second class meeting of the semester.

12. Student Absence for University-Sponsored Events and Activities

If you intend to be absent for a university-sponsored event or activity, you (or the event sponsor) must notify the instructor at least two weeks prior to the date of the planned absence. At that time the instructor will set a date and time when make-up assignments will be completed.

13. Social Security and FERPA Statement

It is the policy of The University of Texas at Tyler to protect the confidential nature of social security numbers. The University has changed its computer programming so that all students have an identification number. The electronic transmission of grades (e.g., via e-mail) risks violation of the Family Educational Rights and Privacy Act; grades will not be transmitted electronically.

14. Emergency Exits and Evacuation

Everyone is required to exit the building when a fire alarm goes off. Follow your instructor's directions regarding the appropriate exit. If you require assistance during an evacuation, inform your instructor in the first week of class. Do not re-enter the building unless given permission by University Police, Fire department, or Fire Prevention Services.

15. UT Tyler Resources for Students

- UT Tyler Writing Center (903.565.5995), writingcenter@uttyler.edu
- UT Tyler Tutoring Center (903.565.5964), tutoring@uttyler.edu
- The Mathematics Learning Center, RBN 4021, this is the open access computer lab for math students, with tutors on duty to assist students who are enrolled in early-career courses.
- UT Tyler Counseling Center (903.566.7254)