

EEL5934-0012(29217) - Special Topics

Introduction to Bulk Acoustic Wave Devices

EEL 5934 Section 0012

Class Periods: Days of week, period, and corresponding time of day

Location: Classroom location

Academic Term: Spring 2024

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Instructor:

Roozbeh Tabrizian

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Office Phone Number: 352-846-3017

Office Hours: Friday, 10:00 am – 11:00 am, LAR 217

Teaching Assistant/Peer Mentor/Supervised Teaching Student:

Please contact through the Canvas website

- TBA

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Course Description

Micro- and nano-scale electromechanical devices operating based on propagation and confinement of bulk acoustic waves in solids are widely adopted for frequency control applications such as clock generation and radio-frequency filtering. Benefitting from several orders of magnitude lower wave propagation velocity, bulk acoustic wave devices operating at microwave frequencies can be created with significantly smaller footprints compared to solid-state electromagnetic counterparts. This makes them superior for integration on / with microsystems that require small size. Further, when implemented in single crystal solids, bulk acoustic wave devices benefits from low intrinsic energy dissipation that enables creation of resonators and waveguides with significantly lower loss and power consumption, when compared to solid-state devices. This course presents an overview on fundamental principles of bulk acoustic wave propagation in solids and discuss theory and applications of bulk acoustic wave devices for frequency control applications.

Course Pre-Requisites / Co-Requisites

NA

Course Objectives

- Understanding fundamental principles of acoustic wave propagation in elastic solids
- Understanding operation principle of bulk acoustic wave resonators and waveguides
- Understanding governing physics of piezoelectric transducers
- Mastering analytical design of piezoelectric bulk acoustic wave resonators
- Understanding acoustic dispersion phenomena
- Modeling dispersion characteristic of bulk acoustic waves in plates
- Getting familiar to applications of bulk acoustic wave devices in commercial electronic systems

Materials and Supply Fees

Not applicable

Required Textbooks and Software

- Bulk Acoustic Wave Theory and Devices
- Joel F. Rosenbaum
- 1988
- 089006265X

Recommended Materials

- Ultrasonic Guided Waves in Solid Media
- Joseph L. Rose
- 2014
- 9781107273610

Course Schedule

- Week 1: Introduction to the Acoustic Equations of Motion / R.T. /Rosenbaum Ch. 1
- Week 2: Prop. of Acoustic Waves in Crystals – 3D Hooke's Law & Christoffel Eq. / R.T. / Rosenbaum Ch. 2 / HW 1
- Week 3: Prop. of Acoustic Waves in Crystals – Prop. in Anisotropic Crystals / R.T. / Rosenbaum Ch. 2 / HW 2
- Week 4: Acoustic Wave Prop. in Bounded Media / R.T. / Rose Ch. 4 / HW 3
- Week 5: Acoustic Wave Prop. in Plates / R.T. / Rose Ch. 6 / HW 4
- Week 6: Piezoelectrically Active Acoustic Wave Prop. / R.T. / Rosenbaum Ch. 4 / HW 5
- Week 7: Electrical Modeling of Acoustic Wave Devices / R.T. / Rosenbaum Ch. 5 / HW 6
- Week 8: Bulk Acoustic Wave Resonators – Operation Principle & Fig. of Merit / R.T. / Rosenbaum Ch. 10 / HW 7
- Week 9: Bulk Acoustic Wave Resonators – Implementation & Applications / R.T. / Rosenbaum Ch. 11 / HW 8
- Week 10: Temperature Sensitivity of Bulk Acoustic Wave Resonators / R.T. / Tabrizian Lecture Notes / HW 9
- Week 11: Acoustic Bandgap Structures/ R.T. / Tabrizian Notes / HW 10
- Week 12: The Impact of Elastic Nonlinearities on Bulk Acoustic Wave Resonators/ R.T. / Tabrizian Notes / HW 11
- Week 13: Bulk Acoustic Wave Clocks and Frequency References / R.T. / Tabrizian Notes
- Week 14: Bulk Acoustic Wave Filters / R.T. / Tabrizian Notes / HW 12
- Week 15: Final Exam

Attendance Policy, Class Expectations, and Make-Up Policy

Excused absences must be consistent with university policies in the Graduate Catalog (<https://catalog.ufl.edu/graduate/regulationsLinks to an external site.>) and require appropriate documentation. Additional information can be found here: <https://gradcatalog.ufl.edu/graduate/regulations/Links to an external site.>

Evaluation of Grades

Assignment	Total Points	Percentage of Final Grade
Homework Sets (12)	100 each	33%
Midterm Exam	100	33%
Final Exam	100	34%
		100%

Grading Policy

The following is given as an example only.

Percent	Grade	Grade Points
90 - 100	A	4.00
87 - 89	A-	3.67
83 - 86	B+	3.33
80 - 82	B	3.00
77 - 79	B-	2.67
73 - 76	C+	2.33
70 - 72	C	2.00
67 - 69	C-	1.67
63 - 66	D+	1.33

60 - 62	D	1.00
57 - 59	D-	0.67
0 - 56	E	0.00

More information on UF grading policy may be found at:

[UF Graduate Catalog](#)[Links to an external site.](#)

[Grades and Grading Policies](#)[Links to an external site.](#)

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/>[Links to an external site.](#). 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/>[Links to an external site.](#). 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/>[Links to an external site.](#). Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>[Links to an external site.](#).

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/>)Links to an external site. 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 varied perspectives and lived experiences within our community and is committed to supporting the University’s core values, including the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of race, creed, color, religion, age, disability, sex, sexual orientation, gender identity and expression, marital

status, national origin, political opinions or affiliations, genetic information, and veteran status.

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
- HWCOE Human Resources, 352-392-0904, student-support-hr@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> [Links to an external site.](#)

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>[Links to an external site.](#), 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**[Links to an external site.](#), 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>[Links to an external site.](#)

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>[Links to an external site.](#)

Career Connections Center, Reitz Union, 392-1601. Career assistance and counseling; <https://career.ufl.edu>[Links to an external site.](#)

Library Support, <http://cms.uflib.ufl.edu/ask>[Links to an external site.](#) 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>[Links to an external site.](#)

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. <https://writing.ufl.edu/writing-studio>[Links to an external site.](#)

Student Complaints Campus: <https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>Links to an external site.; <https://care.dso.ufl.edu>Links to an external site..

On-Line Students Complaints: <https://distance.ufl.edu/getting-help/>Links to an external site.; <https://distance.ufl.edu/state-authorization-status/#student-complaint>Links to an external site..