Radio Frequency Integrated Circuit 2 (Communication Electronics)

EEL 6935 Section XXXX
Class Periods: 2, 1.5 hr, and corresponding time of day.
Location: Classroom location
Academic Term: Spring 2021

Instructor:
Name: Najme Ebrahimi
Email Address: najme@ece.ufl.edu
Office Phone Number
Office Hours: Not defined yet, could be at the same day as class day.

Teaching Assistant/Peer Mentor/Supervised Teaching Student:
Please contact through the Canvas website
Not defined yet

Course Description
Weekly Dates Tue/Thursday, 2 classes per week (1.5 hour per session), (not defined yet),

Course Pre-Requisites / Co-Requisites
– Strong foundation in Electronics and Circuit theory, such as EEE 5374- Radio Frequency Electronics course material and EEE 5320- Analog Integrated Circuit 1
– Strong foundation in algebra and calculus
– Strong foundation in circuit analysis techniques: KVL/KCL
– Strong foundation in transistor level circuit operations
– Strong foundation in microwave theory and techniques

Course Objectives
In this course student will learn the radio frequency communication electronics and integrated circuit design. It will start from RF device modeling to LNA and mixer design towards VCO analysis. Finally, the RF transceiver architecture will be studied.

Materials and Supply Fees

Required Textbooks and Software

Textbook I:
- Title: "High-Frequency Integrated Circuits,"
- Author: Sorin Voinigescu
- Publication date and edition: 2013, any edition
- ISBN number: (ISBN-13: 978-0521873024) (ISBN-10: 0521873029)
- And various publications from IEEE which will be introduced at each lectures.

Textbook II:
- Title: "RF Microelectronics,"
- Author: Behzad Razavi
- Publication date and edition: 2011, 2nd edition
- ISBN number: (ISBN-13: 978-0137134731) (ISBN-10: 0137134738)
- And various publications from IEEE which will be introduced at each lectures.

Software: Every student need to access Cadence and Virtuso with TSMC 180nm CMOS model for simulations and final exam project.

Week 1: Introduction to RFIC and Communication Electronic/ (**Lecture 1 and 2**)/Chapter 2 of RF Microelectronics book and High-Frequency Integrated Circuits Book.

Week 2: Device Modeling (MOS and BJIT RF Device model, noise and stability model/ (**Lecture 3 and 4**)/ Chapter 4 of High-Frequency Integrated Circuits Book.

Week 3: Device Modeling (MOS and BJIT RF Device model, noise and stability model)/ **Lecture 5 and ½ lecture 6**/ Chapter 4 of High-Frequency Integrated Circuits Book/ **HW1 will be assigned**

Passive Components (Inductors, capacitance, resistance performance and model at RF)/ **½ of lecture 6**

Some other references:
"Operation and Modeling of the MOS Transistor" Yannis Tsividis, Mc-Graw Hill
"MOS Transistor Modeling for RFIC Design", Enz et. al., IEEE Transaction on Solid- State Circuits, Vol. 35, 2000

Week 4: Passive Components (Inductors, capacitance, resistance performance and model at RF/ full **lecture 7**/ Chapter 7 of RF Microelectronics book.

Ref for passive component modeling:
"On-chip Spiral Inductors with Patterned Grounded Shield for Si-based RF ICs", Yue and Wond, IEEE JSSC, Vol. 33, Nov. 5, 1998.

Low noise amplifier (LNA) design/ **lecture 8**/ Chapter 5 of RF Microelectronics book and Chapter 7 of High-Frequency Integrated Circuits Book.
Description: LNA with CS, CG stage, with inductive degeneration, MOS LNA, BJT LNA, noise cancelling LNA, Gm-boosting LNA, Noise Figure, LNA linearization, LNA Stability and other non-idealities Considerations (5 lectures required till week 6)

Week 5: LNA with CS, CG stage, with inductive degeneration, MOS LNA, BJT LNA, noise cancelling LNA, Gm-boosting LNA, Noise Figure, LNA linearization, LNA Stability and other non-idealities Considerations (5 lectures required till week 6)/ (**Lecture 9, 10**)/ Chapter 5 of RF Microelectronics book and Chapter 7 of High-Frequency Integrated Circuits Book/ **HW2 will be assigned**

Week 6: LNA with CS, CG stage, with inductive degeneration, MOS LNA, BJT LNA, noise cancelling LNA, Gm-boosting LNA, Noise Figure, LNA linearization, LNA Stability and other non-idealities Considerations (5 lectures required till week 6)/ (**Lecture 11, 12**)/ Chapter 5 of RF Microelectronics book and Chapter 7 of High-Frequency Integrated Circuits Book.

Other references of LNA:
" A 1.5V, 1.5GHz, CMOS Low Noise Amplifier" by Schaeffer and Lee, IEEE JSSC, Vol. 32, no.5, 1997.
" A Comparative Analysis of CMOS Low Noise Amplifiers for RF Applications," by Ge and Mayaram.
" A scalable high frequency noise model for Bipolar Transistor with Application to Optimal Transistor Sizing for Low-noise Amplifier Design', by Voinigescu, et. al, IEEE JSSC, Vol. 32, no. 9, 1997.

Week 7: Circuit biasing for robust manufacturability, Low-frequency amplifier biasing, High-frequency amplifier biasing, Simple biasing schemes, Advanced biasing techniques (process, temperature, voltage independent biasing)– Constant voltage biasing– PTAT current biasing– Constant current biasing, Thermal stability, Electrical Stability, designing temperature stable biasing/ (**Lecture 13, 14**)

Week 8: **Lecture 15: Midterm I**

Lecture 16: Switch, Mixer, Modulator, Demodulator: Frequency Conversion, Mixer Purpose and Fundamentals, Homodyne versus Heterodyne, Bipolar Mixer, MOS Mixer, Single Balanced Mixer, Double Balanced Mixer, Input

matching, LO port and Conversion Gain, Mixer Linearity and Distortion, Mixer noise/ Chapter 9 of "High-Frequency Integrated Circuits" book, Chapter 6 of "RF Microelectronics" book.

Week 9: Switch, Mixer, Modulator, Demodulator: Frequency Conversion, Mixer Purpose and Fundamentals, Homodyne versus Heterodyne, Bipolar Mixer, MOS Mixer, Single Balanced Mixer, Double Balanced Mixer, Input matching, LO port and Conversion Gain, Mixer Linearity and Distortion, Mixer noise/ **lecture 17,18**/ Chapter 9 of "High-Frequency Integrated Circuits" book, Chapter 6 of "RF Microelectronics" book/ **HW3 will be assigned**

Week 10: Switch, Mixer, Modulator, Demodulator: Frequency Conversion, Mixer Purpose and Fundamentals, Homodyne versus Heterodyne, Bipolar Mixer, MOS Mixer, Single Balanced Mixer, Double Balanced Mixer, Input matching, LO port and Conversion Gain, Mixer Linearity and Distortion, Mixer noise/ **lecture 19,20**/ Chapter 9 of "High-Frequency Integrated Circuits" book, Chapter 6 of "RF Microelectronics" book/

Other IEEE Publication references for Mixer:

"Noise in RF-CMOS Mixers: A Simple Physical Model" by Darabi and Adibi, IEEE Transaction on Solid-State Circuits, Vol, 35, No. 1, 2000.
" Noise in Current-Commuting CMOS Mixers" by Terrovitis and Meyer, IEEE Journal of Solid-State Circuits, Vol. 34, No. 6, 1999.
"Monolithic RF Active Mixer Design", by Fong and Meyer, IEEE Transaction on Circuits and Systems II, Vol. 46, No. 3, 1999.
" A Charge-Injection Method for Gilbert Cell Biasing" by MacEachern and Manku, 1998.
" Doubly Balanced Dual-Gate CMOS Mixer' By Sullivan and et al, IEEE Journal of Solid-State Circuits, Vol. 34, No. 6, 1999.
" A Low distortion Bipolar Mixer for Low Voltage Direct-up Conversion and High IF Systems" By Behbahani and et al, IEEE Journal of Solid-State Circuits, Vol. 32, No. 9, 1997.

Week 11: VCO and Oscillators: VCO fundamentals and basic principles, Feedback view of Oscillators, Cross-coupled Oscillators, MOS vs Bipolar LC- Oscillators, Voltage controlled oscillators with wide tuning range and Varactor Q limitations, Phase noise concept and analysis, Low-noise VCO topologies/ **lecture 21,22**/ Chapter 10 of "High-Frequency Integrated Circuits" book, Chapter 8 of "RF Microelectronics" book. **HW4 will be assigned**

Week 12: VCO and Oscillators: VCO fundamentals and basic principles, Feedback view of Oscillators, Cross-coupled Oscillators, MOS vs Bipolar LC- Oscillators, Voltage controlled oscillators with wide tuning range and Varactor Q limitations, Phase noise concept and analysis, Low-noise VCO topologies/ **lecture 23,24**/ Chapter 10 of "High-Frequency Integrated Circuits" book, Chapter 8 of "RF Microelectronics" book.

Week 13: VCO and Oscillators: VCO fundamentals and basic principles, Feedback view of Oscillators, Cross-coupled Oscillators, MOS vs Bipolar LC- Oscillators, Voltage controlled oscillators with wide tuning range and Varactor Q limitations, Phase noise concept and analysis, Low-noise VCO topologies/ **lecture 25**/ Chapter 10 of "High-Frequency Integrated Circuits" book, Chapter 8 of "RF Microelectronics" book/ **Final project for final exam (week 16) will be assigned**

Other IEEE Publication references for VCO:

"A general theory of phase noise in electrical oscillators" By Ali Hajimiri, Tom, Lee, in IEEE Journal of Solid-state Circuits, Feb. 1, 1998.
" A Study of Phase noise in CMOS oscillators" by Behzad Razavi, in IEEE Journal of Solid-state Circuits, Vol. 31, March 1996.

Lecture 26: Midterm II

Week 14: Transceiver Architecture and Design Example with Different Communication Modulations/Demodulations, Considerations/ / **lecture 27, 28**/General Consideration in Transmitter and Receiver architecture, Basic Heterodyne and Homodynes architecture, Direct Conversion transceiver, Zero and Low-IF transceiver, Image-Reject Receiver, On-OFF Keying Transceivers, QAM Modulation, BER and EVM/Chapter 13 of "High-Frequency Integrated Circuits" book, Chapter 4 and 13 of "RF Microelectronics" book.

Other IEEE Publications:
" Design Consideration for Direct-Conversion Receiver," B. Razavi, IEEE, Trans. Circuit and System, vol. 44, June 1997.
" A 1.9-GHz Wideband IF Double Conversion CMOS Receiver for Cordless Telephone Applications," By J. Rudell et. al, IEEE Journal of Solid-state Circuits, Feb. 1, 1998.
"CMOS Mixers and Polyphase Filters for Large Image Rejection," F. Behbahani et.al, IEEE Journal of Solid-state Circuits, Vol. 36, June 2001.

Week 15: Transceiver Architecture and Design Example with Different Communication Modulations/Demodulations, Considerations/ / **lecture 29, 30**/General Consideration in Transmitter and Receiver architecture, Basic Heterodyne and Homodynes architecture, Direct Conversion transceiver, Zero and Low-IF transceiver, Image-Reject Receiver, On-OFF Keying Transceivers, QAM Modulation, BER and EVM/Chapter 13 of "High-Frequency Integrated Circuits" book, Chapter 4 and 13 of "RF Microelectronics" book.

Other IEEE Publications:
" Design Consideration for Direct-Conversion Receiver," B. Razavi, IEEE, Trans. Circuit and System, vol. 44, June 1997.
" A 1.9-GHz Wideband IF Double Conversion CMOS Receiver for Cordless Telephone Applications," By J. Rudell et. al, IEEE Journal of Solid-state Circuits, Feb. 1, 1998.
"CMOS Mixers and Polyphase Filters for Large Image Rejection," F. Behbahani et.al, IEEE Journal of Solid-state Circuits, Vol. 36, June 2001.

Attendance Policy, Class Expectations, and Make-Up Policy
Excused absences must be in compliance with university policies in the Graduate Catalog (https://catalog.ufl.edu/graduate/regulations/) and require appropriate documentation.

Evaluation of Grades
***NOTE:** Course evaluation components should include:

1. At least one component that individually evaluates each student's understanding of course material and ability to apply concepts.
2. At least one evaluation activity that takes place in class.
3. When a project is involved, evaluation rubrics should be explicitly stated.
4. When team work is expected, individual student contribution verification method should be explicitly stated.

If an in-class exam is administered then 1 and 2 are fulfilled. In the case of a project, a project report that is graded per the stated evaluation rubrics and states which work was done by each student in the project team will address both 3 and 4.

Assignment	Total Points	Percentage of Final Grade
Homework Sets (4)	2.5% each	10%
Midterm Exam I	30%	30%
Midterm Exam II	30%	30%
Final Project	30%	30%

Grading:
– Assignments {10%} Analysis/design oriented/Simulation (Hand Analysis, Cadence), 2 week turn around time
4 Assignments, 2.5% each
– Midterm I {30%} In class open book test for 2 hours (Hand Analysis Only)
– Midterm II {30%} In class open book test for 2 hours (Hand Analysis Only)
– Project {30%} Due at final exam period with presentation.

Grading Policy

Percent	Grade	Grade Points
90.0 - 100.0	A	4.00
87.0 - 89.9	A-	3.67
84.0 - 86.9	B+	3.33
81.0 – 83.9	B	3.00
78.0 - 80.9	B-	2.67
75.0 - 79.9	C+	2.33
72.0 – 74.9	C	2.00
69.0 - 71.9	C-	1.67
66.0 - 68.9	D+	1.33
63.0 - 65.9	D	1.00
60.0 - 62.9	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at: https://catalog.ufl.edu/graduate/regulations/

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/.

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/policies/student-honor-code-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.

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
• 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 suppor*t*, 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://care.dso.ufl.edu.

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