EE 631 RF Electronic Circuits

Catalog Description
Distinguishing characteristics of RF circuits; analysis of noise and nonlinearity in circuits; frequency-selective and impedance matching networks; RF amplifiers, oscillators, and frequency conversion circuits; phase-locked loops and their applications.

Instructor
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Office Hours: M, W 12:00 – 2:00 p.m.; 8:30 p.m. – 9:30 p.m.

Schedule
Class: Mondays and Wednesdays, 7:00 – 8:15 p.m., Room E-201
Midterm: Mid-semester – around early October.
Final Examination: Wednesday, December 16, 2015, 7:00 p.m. – 9:00 p.m.

Pre-requisites
Some background in, or familiarity with, each of the following subject areas is necessary:
(1) Microelectronics (electronic devices, models, and circuits)
(2) Circuit analysis (two-ports, network parameters, s-plane, transfer functions)
(3) Signals and systems (spectrum, filtering, feedback, stability)
(4) Transmission lines/microwave circuits (impedance matching, S-parameters)
(5) Random processes (power spectral densities, correlation)

Textbook
(Cambridge University Press, 2004)

Work Load
1. Readings: From textbook; handouts, outside resources, current professional journals
2. Practice Problems: assigned problems, with a problem set per topic
3. Midterm and final examination

Grading
Letter grades, based on the composite performance on each of the following factors
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<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tr>
<td>Homework</td>
<td>20%</td>
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<tr>
<td>Midterm</td>
<td>30%</td>
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<tr>
<td>Final Exam</td>
<td>50%</td>
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Policies
1. On Exams: There are no makeup exams. Midterm and final exam are open-book.
2. On Homework: A problem set assigned on each topic; collected, graded, and returned.

Scope
Design of RF integrated circuits in Silicon CMOS technology
- Passive components and active devices at RF; their characteristics and models
- Performance measures; their calculation from circuit models; their tradeoffs
- Linear circuits (narrowband and broadband amplifiers, LNAs)
- Mildly nonlinear circuits (oscillators, VCOs, PLLs, power amplifiers)
- Strongly nonlinear circuits (High-efficiency power amplifiers, mixers)

Course Objectives
By the end of the semester, the student will be expected to be able to
1. Read and understand current professional literature and journals in the RFIC field
2. Analyze RFICs using linear circuit models, and determine their performance measures
3. Design passive elements and matching circuit employed in silicon CMOS RFICs
4. Interpret performance metrics concerning frequency response, noise & dynamic range
5. Relate CMOS characteristics to material, geometrical, and operating point parameters
6. Use canonical circuit building blocks and design methods to synthesize RF amplifiers, oscillators, mixers, and phase-locked loop circuits (time-permitting).
EE 631  RF Electronic Circuits : Topical Course Outline

1. Domain of use of RF Integrated Circuits in wireless and other applications
   Circuit characteristics required in such applications

2. Series and parallel RLC resonators; Q; lumped L-section impedance transformers.

3. Passive lumped elements employed in RFICs
   Interconnects – transmission line sections; RLC lumped models; skin effect
   Resistors – skin effect, design and layout, models
   Capacitors – types of structures, circuit models, estimation of capacitance
   Inductors – self and mutual inductance; layout, associated parasitics, circuit models
   Transformers

4. Review of MOS device physics, accumulation, depletion, inversion regions
   DC Characteristics; small-signal models; equivalent circuit models
   RF characteristics, $f_T$ and $f_{max}$

5. Time-Domain Characterization of Linear Circuit Response
   Delay; rise-time; approximations for estimation

6. Frequency-Domain Characterization of Linear Circuit and Amplifier Response
   Pole-zero diagrams and frequency-response characteristics
   Approximate methods (open-circuit and short-circuit time constants methods)

7. High frequency amplifier design – narrowband and wideband
   Time-domain and frequency-domain viewpoints

8. Low-Noise Amplifier (LNA) design
   Thermal, shot, flicker noise.
   LNA design based on power and noise constraints.

9. High-Power Amplifier design
   Characterization of Nonlinearity and Dynamic Range
   Single-tone characterizations
   Two-tone characterizations, IIP3

10. Oscillator Fundamentals, Barkhausen oscillation criterion
    Feedback oscillator design

11. Mixers, their performance characteristics, and
    Mixer design and topologies (Gilbert cell)

12. Phase-Locked Loops

Periodicals   Both research journals and trade magazines are good sources of articles for
learning about recent advances, and staying current :

   Electronics Letters
   IEEE Journal on Solid State Circuits
   IEEE Journal on Selected Areas in Communications
   IEEE Microwave and Guided Wave Letters
   IEEE Microwave Magazine
   IEE Proceedings – Part G. Electronic Devices and Circuits
   IEEE Transactions on Microwave Theory and Techniques
   Microwaves and RF
   Microwave Journal
   RF Circuits
   Wireless Systems Design