Winter 2017 Special Topics

CRN	Title	Units	Instructor	Days/Time
22245	289K – Terahertz and mm-Wave Integrated Circuit Design	4	Momeni	TR 4:40-6:00pm
45108	289L - Wide bandgap Semiconductor Devices (WBG-Devices)	4	Chowdhury	TR 10:30-11:50am
44509	289M - Convex Optimization for Electrical Engineering	4	Cui	MW 8:30-9:50am

Title: Terahertz and mm-Wave Integrated Circuit Design

4 units – Winter Quarter

Prerequisite EEC 132 series, EEC 112, or equivalent

Grading: Letter, Design projects (50%), Homework assignments (20%), Mid-term exam (20%), and in-class presentation (10%).

Catalog Description: Brief overview of classical and emerging applications at terahertz (THz) and mm-wave frequency range, Fundamental theory of RF transmitter and receiver including noise figure, nonlinearity and transceiver architectures, Antenna arrays, Design challenges and limitations of passive and active components for mm-wave and terahertz systems, Fundamental limitations in amplifiers and oscillators, Theory and design of mm-wave and THz amplifiers, oscillators and signal sources.

Expanded Course Description

I- Introduction

A- THz and mm-wave applications
B- High-speed Integrated circuits technologies
C- Review of active devices such as small-signal model and frequency response

II- System and Device Specifications

A- Effect of nonlinearity in transceivers such as gain compression and blocking
B- Noise probabilistic definitions and modeling in circuit analysis
C- Noise source correlations and its effect in mm-wave and THz systems
D- Noise sources in CMOS transistor
E- Noise figure and dynamic range definitions and analysis
F- Transmitter and receiver architectures used in THz and mm-wave systems
G- Phased array systems
H- Design challenges and fundamental limitations of passive components for mm-wave and THz systems

III- Signal Amplification

A- Mason's invariant function
B- Maximum oscillation frequency (f_{max})
C- Power gain definitions and relations
D- Power gain limits of active devices
E- Device unilateralization and gain-boosting techniques
F- Tuned amplifier design
G- Noise figure and power gain calculations in tuned amplifiers

IV- Signal Generation

A- Oscillation mechanisms and theory in self-sustained oscillators

B- Signal swing analysis in resonator-based oscillators
C- Oscillator design for frequencies close to f_{max}
D- Harmonic oscillators for mm-wave and THz signal generation
E- Voltage controlled oscillators and the design challenges at high frequencies
F- Frequency multipliers for mm-wave and THz signal generation

Textbooks: Relevant reading material and exercises will be provided by the instructor. Some of the materials are covered in the following textbooks:

1- RF Microelectronics, by Behzad Razavi, Prentice-Hall, 2011.
2- The Design of CMOS Radio-Frequency Integrated Circuits, by Thomas H. Lee, Cambridge University Press, 2003.

Statement of Course Design Projects:

Two projects are assigned, one on mm-wave amplifier and the other on mm-wave oscillator design. The students are expected to use the material learned in the class and do a thorough research to come up with the best circuit architecture for the given specifications. The students are encouraged to be innovative and to understand the detailed operation of the circuit architecture before using it. Next, they use Cadence simulation to design the circuits and verify the functionality. At the end of the quarter students choose to present one of their projects to the class. Their presentation is graded based on different criteria such as clarity and organization.

Instructor: Omeed Momeni, Jane Gu

Course Overlap: There are overlaps in sections II-A, II-E, and II-F with Prof. Gu's graduate course. However materials in these sections are very fundamental to any RF system and would be very useful if covered from different angles in different courses. Moreover these sections provide critical background for the rest of the sections covered in this course. There are also minor overlaps with EEC211 in section II in noise, with EEC222 in section I in small signal models.

CourseTitle – Wide bandgap Semiconductor Devices (WBG-Devices)
Instructor: Srabanti Chowdhury
3 units – Winter quarter: Special Unit
Lecture: 4 units
Prerequisite: Graduate Standing in Engineering, EEC 140B
Grading: Letter; based on homework (30%), mid term paper and presentation (30%), final term paper and presentation (40%).

Catalog Description:
Wide bandgap (WBG) Semiconductor devices including GaN based power and high-voltage transistors, light-emitting diodes, lasers, UV detectors, and photovoltaic. Discussion on emerging WBG semiconductor technologies, including Gallium Oxide and Diamond. All material is from the recent literature, encouraging students to utilize search methods and critically assess the latest research.
Involves Simulation for device design.

Expanded Course Description:
The course attempts to answer the rhetorical question that the electronics industry is asking today- **what is the path beyond Silicon?** This coursework is designed to answer the question by providing a clear picture on the limitations of Silicon and advantages of semiconductor devices those are built with wide bandgap semiconductor. The course will thoroughly discuss the operation principle of these WBG enabled devices, their performance, their current and potential application space, and their demands in the market. We will discuss semiconductor materials to the extent required to understand these devices. The course work will discuss devices based on Gallium Nitride and other III-Nitrides (70%), Diamond (20%) and Oxide (10%). The term papers will include two short projects that will require simulation to conduct device design and analysis.

1. Roadmap and market of wide bandgap semiconductor Applications (present and future)
2. Substrates and materials
    - Various methods of growth (MOCVD, HPVE, MBE, Na-flux, CVD
3. WBG- based High Power High voltage devices
    - Material properties and its advantages
    - Substrates and growth methods
    - Lateral devices (RF and High power)
    - Vertical Device (RF and High power)
    - CMOS- compatible process
    - Characterization and Reliability
    - Thermal management

4. GaN based LEDs and Lasers
    - Growth
    - p-Type GaN and its challenges
    - n-Type GaN
    - Blue and Blue-Green LEDs
    - Room-Temperature Pulsed Operation of Laser Diodes
    - Emission Mechanisms of LEDs and LDs
    - Current Status: Lasers with Self-Organized InGaN Quantum Dots.
5. III-Nitride UV detectors
    - UV Metal Semiconductor Metal Detectors
    - Characterization of Advanced Materials for Optoelectronics by Using UV Lasers
    - Novel III-Nitride Heterostructures for UV Sensors and LEDs
    - Nitride Photodetectors in UV Biological Effects Studies

6 WBG- Photovoltaics for high temperature operation

- Hybrid Solar cells
- Multi-junction solar cells

Textbook/reading:

1. Power GaN Devices
Materials, Applications and Reliability
Editors: Matteo Meneghini, Gaudenzio Meneghesso, Enrico Zanoni
2. The Blue Laser Diode – the complete story
Shuji Nakamura, Stephen Pearton, Gerhard Faso
3. UV Solid-State Light Emitters and Detectors
Editors: Shur, Michael S., Zukauskas, Arturas
4. Notes provided by the instructor

Required Software:
Silvaco Atlas

Convex Optimization for Electrical Engineering
EEC 289M

Instructor: Prof. Shuguang (Robert) Cui
Office: 3131 Kemper Hall
Phone: 530-752-7395
Email: sgcui@ucdavis.edu

Units: 4

Course description: With advancement in computing science, systematic optimization, especially convex optimization, has been recognized as a powerful tool in communication system design, circuit design, efficient signal processing, and other electrical engineering fields. As electrical engineers, especially for graduate students, it is essential to learn basic optimization techniques and apply them in on-going research. In this class, we start with an EE-oriented introduction of convex optimization including convex set, convex functions, convex optimization problems, KKT conditions and duality, unconstrained optimization, and interior-point methods for constrained optimization. We then devote the rest of the class to specific application examples in electrical engineering: communication/information theory, signal processing, circuit design, and networking, which are based on state-of-art research papers.

Topics:

- Convex Sets and Convex Functions
    - Definition of convex sets with examples in electrical engineering (3 hours)
    - Definition of convex functions, basic properties, with examples in electrical engineering (3 hours)
    - Quasiconvex, log-concave, and log-convex functions, with examples in electrical engineering (3 hours)
- Convex Optimization Problems
    - Convex optimization problems with examples in electrical engineering (3 hours)
    - Linear, quadratic, and geometric optimization problems, with examples in electrical engineering (3 hours)
    - Semi-definite programming with examples in electrical engineering (2 hours)
- KKT Conditions and Duality
    - The Lagrange dual function and dual problem (6 hours)
    - Optimality conditions (4 hours)
- Unconstrained and Constrained Convex Problems
    - Unconstrained optimization (3 hours)
    - Interior Point Method for constrained optimization (3 hours)

- Applications Examples
  - Information/Communication Theory (3 hours)
  - Circuit Design and Signal Processing (3 hours)
  - Other engineering problems (5 hours)

Recommended Texts:

1. S. Boyd and L. Vandenberghe, *Convex Optimization*, http://www.stanford.edu/~boyd/cvxbook/
2. Ben-Tal and A. Nemirovski, *Lectures on Modern Convex Optimization*, SIAM Press.
3. D. Bertsekas, Nonlinear Programming. Athena Scientific.

Grading Structure

10 Homework sets, 20pts/each, in average worth 20 points
One midterm, worth 30 points
Class participation (quizzes and class attendance), in average worth 10 points
Final Project, worth 40 points
