Integrated Circuits & Systems, Electronics

Prof. Mingoo Seok
• Computing: AI/ML, physical system simulation.
  ➢ New bio-inspired architecture, in-memory computing, hybrid computing

• Internet of Things (IoT)
  ➢ Ultra low power analog, digital, RF circuits

• Electrified cars/transportation
  ➢ Power electronics, battery mgt.

• Wireless comm. (5G, 6G..)
  ➢ Millimeter-wave, spectrum sensing

• Electronics for biomedical app.
  ➢ Implants, biochips

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Graphic (platform): tesla.com
Half trillion dollar industry → good job prospects
Vertical integration trends: System company (e.g., Apple), and traditional SW companies (e.g., Google, MS, Alibaba, Amazon), are now building their own chips → even better job prospects
Most of the MS students who worked in my lab had no problem to find a job at the graduation. I heard the same from a few other faculty members in this area
ELEN 4312: Analog Electronic Circuits

Syllabus:

• CMOS and Bipolar transistor small signal & large signal behavior
• Analog biasing techniques, digitally assisted biasing techniques, matching and layout considerations
• Single-ended, differential and multistage amplifier design, common mistakes pitfalls
• Analysis techniques for complex analog circuits and blocks
• Bandwidth considerations, bode-plots & frequency response
• Negative feedback theory and implementation
• Stability criteria, compensation techniques, avoiding undesired oscillations
• Design project: Varies with year (high-frequency amplifier, feedback amplifier, etc.)

Instructor:

Prof. Shahriar Shahramian

Summary:

Introductory-yet-detailed analog circuits course that prepares the student for an advanced analog IC class. **Fundamental course for any electrical engineer.** An opportunity to learn critical circuit analysis techniques, design considerations and to develop an intuition about complex analog circuits.
ELEN 4215: Analog Filter Synthesis and Design

Overview:
Course covers the design of analog filters, from designing transfer functions that will achieve a desired filter specification, to transfer functions realization using a variety of passive and active filter topologies.

Instructor:
Prof. Tod Dickson

Example Application:
Filters in a cell phone receiver

Syllabus:
- Filter specifications, transfer functions
- Filter approximations (Butterworth, Chebyshev, Elliptic, Bessel)
- 1st & 2nd order passive & active (op-amp-RC) filter implementations
- Integrator-based biquads
- MOSFET-C filters
- Gm-C filters
- Filter tuning
- Ladder filters & active realizations
- Discrete-time signaling & switched capacitor filters

Course Renewed!
EECS 4321: Digital VLSI

Syllabus:

- Design and analysis of high speed logic and memory.
- Digital CMOS and BiCMOS device modeling.
- Integrated circuit fabrication, layout & CAD tools.
- Interconnect and parasitic elements.
- Static and dynamic techniques.
- Worst-case design; heat removal and I/O; yield and circuit reliability.
- Logic gates, pass logic, latches, PLAs, ROMs, RAMs, receivers, drivers, repeaters, sense amplifiers.
- Design project: full-custom microprocessor design

Instructor:

Prof. Ken Shepard

Summary:

Introductory-yet-detailed digital VLSI course that introduces the student to transistor-level (custom) digital design and CAD tools for digital IC design.
EECS 4361: Power Electronics

**Syllabus:**

- Non-sinusoidal power computations, modeling, and simulations
- Introduction and discussion of the main power electronic switching devices: power diodes, IGBTs, MOSFETs, etc.
- Analysis and design of power converters:
  - Single and three-phase rectifiers
  - DC/DC converters,
  - Isolated DC power supplies
  - Single and thee-phase inverters
- Discussion of power electronic applications: Plug-in vehicles, renewable energy, high-voltage DC transmission
- Students develop an open-ended experimental project and write a research-paper styled report
- Best paper is considered for publication!

**Instructor:**

Prof. Matthias Preindl

**Summary:**

Introduction to solid-state electric power conversion. By the end of the class, students are able to design, analyse, and simulate converter circuits.
CSEE 4823: Advanced Logic Design

**Syllabus:**
- Combinational, sequential gates
- Arithmetic circuits
- Logic circuit synthesis
- Logic circuit analysis
- Advanced logic: asynchronous, testing

**Project:**
- Group project to build a medium-size logic circuit
- FFT, neural network inference engine, etc.
- Verilog-RTL coding, gate-level logic synthesis, verification, post-synthesis static timing analysis and power characterization
- Use industrial CAD tools and the modern CMOS process to do above

**Instructor:**
Prof. Mingoo Seok
ELEN 6320: Millimeter-Wave ICs.

Syllabus:

• What's next in wireless communication and radar? Millimeter waves!
• Introduction to millimeter-wave (30GHz and above!) systems and applications.
• Phased arrays – the most exciting technology in 5G cellular
• Designing millimeter-wave wireless circuits using silicon (CMOS and SiGe)
• mmWave amplifier design
• mmWave mixers for frequency translation.
• mmWave oscillators
• mmWave frequency synthesis
• Design project: design of a mmWave source using VCO and frequency multiplier

Instructor:


Summary:

Cutting-edge class that trains students to design ICs for emerging mm-Wave applications.
ELEN 6324: RF/Microwave Measurement

This hands-on lab-based course covers the principles behind RF and microwave simulation and metrology, key skills in scientific research and industrial development.

Concise Syllabus:

- Do You Know Your Lab? DC to Light!
- RF and Microwave Basics
- Theory of S-Parameters
- RF Passive Components
- Principles of Network Analysis Measurements
- Principles of Large-Signal Simulations and Measurements
- Principles Behind Spectrum Measurements
- Principles Behind Noise Measurements
- Principles of Time Domain Measurements
- Frequency-Conversion Measurements

Instructor: Prof. Harish Krishnaswamy

Evaluation: midterm exam (20%), final exam (30%), lab modules (50%).

Enrollment: Capped at 27 students. Please send Prof. Krishnaswamy an email by September 5th if you are interested. Qualified students will be admitted on a first-come-first-serve basis.

New course number!
General Tips

• **Ask for advice!**
  – Academic advisors, instructors, fellow (senior) graduate students, …

• Think about your *overall program*

• M.S. students, consider one of the *concentrations*: e.g., “Integrated Circuits and Systems”
  – see [http://bulletin.engineering.columbia.edu/optional-ms-concentrations](http://bulletin.engineering.columbia.edu/optional-ms-concentrations)
  – Advisors: Kinget, Krishnaswamy, Preindl, Seok, Shepard, Tsividis, Zukowski

• M.S. students, consider getting involved with *research*
  – ELEN 6001 Advanced Project Courses
  – First, need to find a research project advisor
  – See [http://www.cisl.columbia.edu](http://www.cisl.columbia.edu)
  – Visit the open labs!
Typical Course Offerings in Other Semesters

(subject to change)
ELEN 4314: Communication Circuits

Concise Syllabus:

- Nonlinearity, distortion, IMD, intercept points, dynamic range.
- Introduction to noise, PSD, BJT/MOS noise models, noise bandwidth, NF.
- Transformers, resonant circuits, quality factor (Q), impedance matching.
- Bandpass amplifier design.
- Power amplifiers (Class A-D).
- Oscillators (startup, describing function analysis, negative-resistance, feedback osc., LC, Colpitts ..).
- Multipliers and mixers.
- Amplitude, phase and frequency modulators and demodulators.
- Introduction to PLLs.
- Design project: Varies by year (AM transmitter, FM transmitter, metal locator, Theremin, etc.)

Instructor:

Prof. Yannis Tsividis

Summary:

Introductory-yet-detailed communication circuits course that prepares the student for an advanced communication IC class.
ELEN 6302: MOS Transistors

Syllabus:

- Introduction and background review
- MOS two- and three-terminal structures
- The MOS transistor as a four-terminal device
- Strong, moderate, and weak inversion models
- Short- and narrow-channel effects
- Scaling considerations in VLSI
- Quasistatic and nonquasistatic operation
- Charge modeling and large-signal transient response
- Small-signal modeling and noise.
- Project.

Instructor:

Prof. Yannis Tsividis

Targeted audience:

The understanding provided in this graduate course is essential not only for device modelers, but also for designers of high-performance circuits.
ELEN 6312: Advanced Analog ICs

Concise Syllabus:

• Overview of basic MOS device physics.
• Passive and Active Current Mirrors.
• Single-stage MOS amplifiers - basics.
• Frequency-response of single-stage MOS amplifiers.
• Feedback.
• Noise.
• Operational Amplifiers.
• Stability and Frequency Compensation.
• Bandgap References.
• Switched Capacitor Circuits.
• Nonlinearity and Mismatch.
• Design project: design of a single-stage of a pipelined ADC in 0.18\textmu m CMOS.

Instructor:

TBD

Summary:

Detailed analog circuits course that focuses on integrated CMOS implementations.
ELEN 6316: Analog-Digital Interfaces in VLSI

Overview:
Detailed study of data converter architectures and circuits found at the boundary between analog and digital circuit domains. Course will cover data converter metrics, architecture tradeoffs, and implementation details for Nyquist-rate and oversampled ADCs and DACs.

Instructor:
Prof. Tod Dickson

Syllabus:
- Dynamic range: noise, distortion, SNDR
- Component matching
- Data converter specifications (resolution, quantization error, INL, DNL)
- Sample-and-hold circuits, comparators, switched-capacitor techniques
- Nyquist rate DACs
- Nyquist-rate ADCs (flash, SAR, pipeline, integrating)
- Time interleaving techniques
- Digital assistance/calibration techniques
- Oversampled (delta-sigma) data converters
ELEN 6318: Microwave Circuit Design

Concise Syllabus:

• Basic Microwave Design Principles:
  • Transmission lines & Smith-chart, coupled transmission lines
  • S-parameters, Microwave networks
  • Impedance matching and tuning
• Practical Microwave Components:
  • Various transmission lines, power dividers & couplers
  • Active and passive microwave devices
• Design of active microwave circuits
  • Amplifiers: narrow-band, low-noise, broad-band, power amplifiers
  • Non-linear circuits: oscillators, multipliers, mixers
• Simulation and measurement tools for microwave circuits
• A microwave circuit design project (using microwave CAD) is an integral part of the course.

Instructor:

Prof. Yves Baeyens

Summary:

Advanced class that teaches the design with non-lumped circuit elements for microwave applications.
EECS E6321: Advanced Digital Circuits

Syllabus:

• Advanced topics in modern VLSI hardware design
• Low-power and ultra-low-power design; low-leakage and ultra-low-leakage design; variation tolerant design; on-chip power supply; design for reliability; embedded memory circuits;

Design project:

• Building a medium/large-size digital chip from verilog-HDL to logic synthesis to automatic placement and routing to static timing and power analysis

Pre-requisites:

• 4321 and 4823

Instructor:
Prof. Mingoo Seok
ELEN 6350: VLSI Design Lab.

Concise Syllabus:

• Design & test of a large-scale deep submicron CMOS integrated circuit.
• The class will divide up into teams.
• Lectures introduce circuit design issues related to the projects, CAD tools, chip integration issues, packaging, ESD, and design for test., may divide up into teams to work on different aspects of a single mixed-signal circuit.
• Instructor provided projects or student proposed project. Project emphasis is on (small) system-on-chip designs

Pre-requisites:
• 4312: Analog Electronic Circuits
• 4321: Digital VLSI Circuits

Timeline:
• Spring 2016: Chip Design + Tape-out
• Summer 2016: Chip Fabrication
• Fall 2016: Test Board design + Chip Test

Instructor:
Prof. TBD

Summary:
Get ready to design your own chip!
ELEN 6314: Advanced Comm. Circuits

**Syllabus:**

- **Focus on Radio-Frequency Integrated Circuit Design**
  - Overview of communication systems
  - Receiver and transmitter architectures
  - Noise, sensitivity, and dynamic range
  - Nonlinearity and distortion
  - Low-noise RF amplifiers, mixers, and oscillators
  - Phase-locked loops and frequency synthesizers
- Typical applications discussed include wireless RF transceivers.
- Computer-aided analysis techniques are used in homework(s) and a design project.
- *Design Project:* teams of 2 students design RF receiver front end in CMOS

**Instructor:**

Prof. TBD

**Summary:**

*Advanced* class that trains students to design ICs for RF and wireless communications applications.
Questions?