# EE 410 – Linear Electronic Design

**Designation:** EE elective course for electrical engineering majors.

**University Bulletin Description:** EE 410 (3) Linear circuit design via integrated circuit processes; A/D converters, switched capacitor filters, phase lock loops, multipliers, and voltage- controlled oscillators. Prerequisite: EE 311.

**Prerequisites by Topics:**
1. Have an appreciation for different device properties and their use (and limitations) in circuit applications;
2. Understand the properties of different circuit and sub-circuit topologies and their appropriate use in amplifier design;
3. Understand the bandwidth constraints imposed by device and circuit capacitances, and the appropriate use of amplifier topologies to mitigate frequency response limitations;
4. Have an appreciation for the analysis and design of different amplifiers such as basic one-transistor amplifiers, differential pairs, multistage amplifiers, and operational amplifiers;
5. Understand feedback terminology and concepts as they apply to amplifier analysis and design; develop an appreciation for the design tradeoffs introduced by negative feedback.

**Textbook/Required Materials:**
Neamen, Donald A., Microelectronics: Circuit Analysis and Design, 3rd edition, McGraw Hill, 2007, ISBN 978-0-07-252362-1—ISBN 0-07-252362-X.

**Learning Outcomes:**
This elective course for seniors and graduate students builds on and extends work done in the electronics sequence (EE 310, EE 311). Through lecture, laboratory, and out-of-class assignments, students are provided learning experiences that enable them to:
1. Understand the internal structure of the op amp, including the effects of circuit architecture on op-amp performance;
2. Understand the origins of op-amp bandwidth and slew-rate limitations, input DC offset voltage and current, and common-mode voltage limitations;
3. Understand contemporary op-amp design techniques including rail-to-rail swing, dynamic frequency compensation, low-voltage, and low-power designs;
4. Design active filters, sinusoidal and nonsinusoidal oscillators, comparators, timers, voltage and current regulators, and DC-DC converters using op amps and linear integrated circuits;
5. Understand the origins of and methods of analyzing noise in op-amp circuitry;
6. Understand D/A and A/D conversion techniques, phase-locked loops, and frequency synthesizers;
7. Complete a laboratory design project in the area of analog circuit design, applying knowledge learned in the course.

**Topics:**
1. Operational amplifier internal design techniques (5 classes)
2. Wideband and current-feedback op amps (3 classes)
3. Op-amp nonideal parameter limitations and their origins (3 classes)
4. Contemporary op-amp design techniques (3 classes)
5. Filter topology, active filters, switched-capacitor filters (6 classes)
6. Oscillators, comparators, timers (6 classes)
7. IC power amplifiers, voltage regulators, DC-DC converters (6 classes)
8. D/A and A/D converters (3 classes)
9. Noise in electronic circuits (3 classes)
10. Phase-locked loops and frequency synthesis (4 classes)

11. Student project presentations (2 classes)

**Class/Laboratory Schedule:** Three 50-minute lectures and one 2-hour laboratory per week.

**Computer Usage:**
Multisim is used for analysis of circuitry in class, in the lab, and on homework assignments.

**Laboratory Projects/Assignments:**
1. Design and prototyping of a complete three-stage op-amp (4 weeks);
2. Design, prototyping, and presentation of a student-defined semester project (10 weeks).

**Contribution to Meeting the Requirements of Criterion 5. Curriculum:**
This course contributes to both the engineering topics and design components.
The third in a series of circuit design courses, EE 410 emphasizes linear electronic circuit design using integrated circuit processes, as well as applications, at a level appropriate for seniors and graduate students. Topics pertaining to economics and manufacturability are considered in the context of electronic circuit design and construction.

**Relationship to Program Outcomes:**
O.1.1. Graduates will possess mathematics skills necessary for electrical engineering.
O.1.3. Graduates will have attained computer proficiency.
O.2.1. Graduates will understand how to analyze and design simple electrical/electronic circuits.
O.2.2. Graduates will understand electronic devices.
O.2.3. Graduates will understand the basic concepts of linear systems and how they interact with continuous-time signals.
O.3.1. Graduates will have in-depth technical knowledge in one or more areas of specialization.
O.3.2. Graduates will have practical understanding of the major electrical engineering concepts and demonstrate application of their theoretical knowledge of the concepts.
O.4.1. Graduates will interact with industry both within and outside of a classroom setting.
O.4.2. Graduates will develop an appreciation of continuing educational and professional development.
O.5.1. Graduates will have good teamwork skills.
O.5.2. Graduates will possess good oral and written communication skills.
O.6. Graduates will appreciate their role as engineers in society.

**Prepared by:** Mark J. Wharton **Date:** March 15, 2008