Master Course Description for EE-333 (ABET sheet)

Title: Analog Circuit Design

Credits: 5

UW Course Catalog Description

Coordinators: Chris Rudell, Professor, Electrical and Computer Engineering, Hossein Naghavi, Assistant Professor, Electrical and Computer Engineering

Faculty available to teach course: Hossein Naghavi, Chris Rudell

Goals: To teach modern analog (embedded) system design techniques using the latest commercially available integrated circuit technology.

Learning Objectives: At the end of this course, students will be able to:

1. *Understand and apply* the specifications and limitations of commercially available operational amplifiers and other analog integrated circuits.
2. *Design* analog subsystems that employ feedback using operational amplifiers and other analog integrated circuits.
3. *Design* instrumentation and signal conditioning circuits using operational amplifiers.
4. *Design* active filters using operational amplifiers and other analog integrated circuits.
5. *Evaluate* the stability of operational amplifier systems and *design* frequency compensation circuitry.
6. *Design* signal generators and nonlinear circuits using operational amplifier circuits.

Textbook: S. Franco, *Design with Operational Amplifiers and Analog Integrated Circuits, 4th Ed.*, McGraw-Hill, 2015. ISBN # 978-0-07-802816-8.

Reference Texts:

1. P. R. Gray, P. J. Hurst, S. H. Lewis, and R. G. Meyer, *Analysis and Design of Analog Integrated Circuits, 4th Ed.*, John Wiley & Sons, 2001. ISBN # 0-471-32168-0.
2. J. Graeme, *Amplifier Applications of Op Amps*, McGraw-Hill, 1999. ISBN # 0-07-134642-2.
3. W. Jung, Ed., *Op Amp Applications Handbook*, Analog Devices / Newnes, 2005. ISBN # 0-7506-7844-5.

Prerequisites by Course:

E E 233; E E 242; and either E E 280, or E E 331

Prerequisites by Topic:

1. Circuit Theory (EE 233): Analysis of circuits with sinusoidal signals. Phasors, system functions, and complex frequency. Frequency response. Basics on operational amplifiers.
2. Signals, Systems, and Data I (EE 242): Basic signals, including impulses, unit steps, periodic signals, and complex exponentials. Fourier series and transforms. Linear, time-invariant filters.
3. Exploring Devices (EE 280): Introduction to modeling and principles of physics relevant to the analysis of electronic devices (diodes, field-effect transistors, or bipolar junction transistors).
4. Devices and Circuits I (EE 331): Physics, characteristics, analysis, and design of simple circuits using semiconductor diodes and field-effect transistors.

Topics:

1. Operational amplifier circuits (Franco Chapters 1 and 2) [2 weeks]
2. Static/dynamic op amp limitations (Franco Chapter 5) [1 weeks]
3. Stability and compensation (Franco Chapter 8) [2.5 weeks]
4. Nonlinear circuits (Franco Chapter 9) [1 week]
5. Active filters (Franco Chapters 3 and 4) [1 week]
6. Signal generators (Franco Chapter 10) [1 week]
7. Voltage regulators (Franco Chapter 11) [1.5 weeks]

Course Structure: The class meets for either four 50-minute or two 110-mintute lectures, and one lab meeting of 170 minutes per week. Homework is assigned for a total of 5 assignments over the quarter. This class has 10 lab sessions; 5 of them are assigned to the hardware lab, and the other 5 are assigned to the software lab (LTspice, Altium Designer, or KiCAD). Laboratory work constitutes a significant focus of the class and is organized into smaller laboratory sections, typically 24 students divided into 8 groups of 3 each, which meet weekly.

Computer Resources: H

LTspice is used for circuit simulations, and Altium Designer or KiCAD are used for circuit layout drawings. The Arduino IDE is also used for controlling analog circuits in the lab sessions. For general-purpose mathematical analyses, students can use Python.**Laboratory Resources:** The main electronics laboratory in room 137 supports this class with benches equipped with oscilloscopes, power supplies, function generators, digital multimeters, test leads, and computers equipped with data acquisition pods. EE store will deliver a component box to each student who will need it for the hardware lab session during the quarter. The cost of the component box is covered by the lab fee (~ $50).

Laboratory Structure:

This course includes five extensive lab sessions where students learn how to work with various practical circuits using operational amplifiers and other off-the-shelf integrated circuits.

Lab 1: Review of basic operational amplifier circuits (basic mathematical operations and first-order active filters); Design an absolute and differential thermometer controlled by an Arduino board.

Lab 2: Design of heartbeat detector circuit using operational amplifiers; Design of several operational amplifiers nonlinear circuits, including comparators and Schmitt triggers; Design of pulse width modulators using 555 timers.

Lab 3: Design of digitally controlled Wien bridge oscillators using a digital potentiometer and Arduino controller board; Design of second-order active filters.

Lab 4: Adjustable notch filters using Arduino boards and digital potentiometers; Switched capacitor RC filters; Simple voltage regulator and voltage reference circuits using operational amplifiers.

Lab 5: Linear voltage regulators; Switched capacitor voltage power supply; Optical communication link using infrared transceivers.

Grading: Laboratory Projects (50%), Homework (40%), Class participation (10%)

ABET Student Outcome Coverage: This course addresses the following outcomes:

H = high relevance, M = medium relevance, L = low relevance to course.

(1) *An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics* **(H)** The lectures, homework and design projects deal with the application of circuit theory to electronic system analysis and design. Mathematical formulations are commonplace throughout the course. Both the homework and laboratory design projects involve a large component of solving engineering problems. The laboratory design projects are open-ended and additionally require the students to identify and formulate the principle issues associated with the engineering problems.

(2) *An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors* **(M)** The homework problems and laboratory design projects are phrased in terms of realistic constraints such as cost, size, weight, power consumption, alignment ease, component variation, and manufacturability.

(3) *An ability to communicate effectively with a range of audiences* **(M)** Design project reports are required to be styled and formatted like a product specification sheet. Emphasis is placed upon clear descriptions of circuit operation, illustrative block diagrams, industry acceptable schematic diagrams, a formal bill of materials with full component sourcing, and proper references to design standards.

(4) *An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet*

objectives **(M)** The design problems are addressed by teams of 2-3 students who must organize themselves and divide up the work among them.

(5) *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions* **(M)** The course involves hands-on laboratory design work in which experimentation is a necessary component. Students must devise their own experiments to test their designs and make engineering judgments based on those outcomes to redesign the system.

(6) *An ability to acquire and apply new knowledge as needed, using appropriate learning strategies* **(M)** The course focuses on modern electronic circuit design which involves researching, selecting, and applying new components. Students are responsible for learning this on their own.

Prepared By: Chris Rudell, Hossein Naghavi

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