**1. Department, number, and title of course**

4400:360 PHYSICAL ELECTRONICS

**2. Course (catalog) description**

The material of this course covers operational amplifiers, diodes, field effect transistors, and bipolar junction transistors, along with circuit design involving these components and devices.

The overall objective of this course is to develop a comprehensive knowledge of the basic electronic components, devices, and techniques of modern electronic circuit design.

**3. Prerequisite(s)**

4400:263 Switching and Logic
4400:332 Circuits II

4. Textbook(s) and/or other required material
Sedra/Smith, "Microelectronic Circuits", Oxford University Press, New York, 2004, ISBN 0-19-514251-8 (required).

Richard C. Jaeger, and Travis N. Blalock, "Microelectronic Circuit Design," McGraw-Hill, Boston, MA, 1997, ISBN 0-07-232099-0 (recommended).

**5. Course objectives**

The course has three main objectives. The first is to gain a basic understanding of the physical principles related to the design, operation and manufacturing of discrete electronic component such as p-n junctions, BJT's, and FET's. The second objective is to learn to choose the right models (small-signal, large-signal analysis) and right tool (mesh analysis, nodal analysis) when analyzing a given problem. The third objective is to learn the basic principles of electronic design and integrate discrete electronic components into integrated systems.

**6. Topics covered**

**1. <u>Introduction to Electronics</u>**

Classification of electronic signals. Important concepts from circuit theory. Frequency spectrum of electronic signals. Amplifiers. Frequency response of amplifiers. Converters.

**2. <u>Operational Amplifiers</u>**

The differential amplifier. The ideal amplifier. Analysis of circuits containing ideal operational amplifiers: The inverting amplifier. The noninverting amplifier. The unity-gain buffer amplifier. The summing amplifier. The difference amplifier. The instrumentation amplifier. A low pass filter. The integrator. Two-port representations. Large signal limitations-slew rate and full-power bandwidth. Non ideal operational amplifiers. Common mode rejection ratio (CMRR). Circuit design examples. Operational Amplifier Applications. Circuits using positive feedback: The comparator. The Schmitt trigger circuit. The astable multivibrator. Applications.

**3. <u>Diodes</u>**

Solid state electronic materials. Drift currents in semiconductors. Mobility. Resistivity in silicon. Impurities in semiconductors. Mobility and resistivity in doped semiconductors. Diffusion current. Total current. The effect of dopants and impurities on the signal performance of the semiconductor circuits. Industrial applications and examples. SPICE model of solid state transport parameters. Diodes: The *pn* junction diode. The i-v characteristics of a diode. The diode equation: a mathematical model for the diode. Diode characteristics under reverse, zero, and forward bias. *pn* junction capacitance. Schottky barrier diode. Diode circuit analysis. Load-Line analysis. Analysis using the mathematical model of diode. The ideal diode model. Constant voltage drop model. Multidiode circuits. Analysis of diodes operating in the breakdown regime. Zener diodes. Half-wave rectifiers. Photodiodes, avalanched photo detectors (APD), solar cells, and light-emitting diodes. SPICE model for diodes.

**4. Field-Effect Transistors (FETs)**

Characteristics of the MOS capacitor. Structure of the NMOS transistor. Quantitative I-v behavior of the NMOS transistor. Saturation of the I-v characteristics. Channel-length modulation. Transfer characteristics and the depletion-mode MOSFET. Body effect or substrate sensitivity. PMOS transistors. MOSFET circuit symbols and model summary. Biasing the MOSFET. Capacitances in MOS transistors. SPICE model for field-effect transistors. Detailed electronic circuit design examples with MOSFETS.

**5. Bipolar Junction Transistors (BJTs)**

Physical structure of the bipolar transistors. The transport model for the npn transistor. The pnp transistor. Equivalent circuit representations for the transport models. The operating regions of the bipolar transistor. The I-v characteristics of the bipolar transistors. Simplified model for the cut-off region. Model simplifications for the forward-active region. Simplified models for the reverse-active region. Modeling operation in the saturation region. Biasing the BJT. SPICE Model for bipolar junction transistors. Detailed electronic circuit design examples with BJTs.

**6. Small-Signal Modeling and Linear Amplification**

The transistor as an amplifier. Coupling and bypass capacitors. Circuit analysis using dc and ac equivalent circuits. Introduction to small signal analysis. Small-signal modeling of the diodes. Small-signal models for bipolar junction transistors (BJT)'s. The BJT common-emitter (CE) amplifier. Signal models for field-effect transistors (FET)'s. The common-source (C-S) amplifier. The input and output resistances of the C-E, and C-S amplifiers. Design guide for C-E and C-S amplifiers with resistive loads. Amplifier power and signal range. Detailed examples of electronic circuit analysis: dc (Q-point) and ac solutions. Summary and comparison of the small-signal models of the BJT and FET. SPICE modeling.

**7. Class/laboratory schedule, i.e., number of sessions each week and duration of each session**

Fall semesters (three 50-minute sessions a week)

**8. Contribution of course to meeting the professional component**

The course requires knowledge of physical electronics, with emphasis on the physics of semiconductors, electronics, and mathematics. The course requires two design projects using PSPICE, two projects, and many of the homework problems involve design of circuits given specifications. The course contributes in a small way to general education, in that it lays down the foundations for further study and exploration of new engineering disciplines such as electronic devices, detectors, instrumentation, power electronics, and so on.

## 9. Relationship of course to program objectives

The course requires application of physics, with emphasis on the physics of semiconductors, basic electromagnetic theory, statistical mechanics, and atomic theory (PO1). It also requires application of engineering principles to the formulation, and solution of engineering problems (PO1), as students must process all the course material and decide which equivalent circuit model is appropriate for a certain electronic circuit topology. The course also has a significant design component; it includes three- four design projects, experimental and simulations, for which the students are asked to design circuits meeting given specifications (PO3). The design projects give the students practice in using standard electrical engineering tools such as PSPICE, Microsoft Word , MATLAB, EXCEL (PO7), in addition to an experimental project and the associated formal written reports require the students to communicate in written form (PO6). Problems related to the critical study of emerging trends semiconductor technologies as well as applications of physical electronics into different technological areas are assigned to students (PO8).

## Examinations

Two midterms will each count 20% towards the course grade, and will be given during the lecture period. The comprehensive final exam, which counts for 30% of the course grade will be given as scheduled by the registar. Exams are closed book. Calculators are allowed.

## Homework Sets

Homeworks count 10% towards the course grade. Homeworks will not be accepted late. The work that you turn must be completely your own.

## Design Projects

Design projects count 20% towards the course grade. No project will be accepted more than five days late.