University of Hartford, Ward College of Technology
Prepared and Taught by the Department of Electronic Engineering Technology
In Academic Year 2000 - 2001

COURSE INFORMATION DOCUMENT

EL 351 - Linear Integrated Circuits
Spring Semester, 2001
This Course is Normally Taken by EET Students in Fourth Year, Fall Semester

2000-2001 Bulletin Statement:

EL 351 Linear Integrated Circuits [4] Analysis of differential amplifiers, operational amplifier circuitry, performance specifications of operational amplifiers. Applications of operational amplifiers such as wideband amplifiers, true differential amplifiers, differentiators, integrators, D/A and A/D converters, active filters, sample and hold circuits. Instrumentation and isolation amplifiers, frequency to voltage/voltage to frequency converters, voltage and current regulators. Three lecture hours, three-hour lab. Prerequisites: EL 243, EL 244, MTH 241, UP 242. Laboratory fee.

Credits: 4 Credits (3 for lecture, 1 for laboratory)

Course Hours: Lecture, 3 hours/week for 14 weeks = 42 contact hours, Laboratory, 3 hours/week for 14 weeks = 42 contact hours, Total Hours = 84 contact hours.

Many students spend 2 to 3 hours outside of class for each contact hour.

Required Textbook: *Operational Amplifiers with Linear Integrated Circuits*, Stanley, 3rd Ed., Merrill Publ.

Supplemental Materials: Scientific calculator (TI-86 is recommended), standard laboratory tools.

Course Coordinator
and Prepared By: Prof. Walter Banzhaf, P.E._____

Approved By: Department Chair_____

Notes:

1. The topics listed below are guidelines; what is actually covered in the course may vary slightly. Students will be notified in writing of any variances from what is printed below.

2. Students are responsible for reading this document. Questions should be referred to the course instructor.

3. This document should be retained by the student for future needs (e.g. transfer credits), as the course is revised periodically, and it may be difficult or impossible to obtain a copy.

Goals:

This is a comprehensive in-depth required technical course in the student's major. It includes aspects of all technical courses that precede it, and builds on them. The insights provided by this course will allow students to understand a wide range of applications of op-amps and linear integrated circuits in both analog and digital circuits. The laboratory part of this course reinforces the important basics of op-amps and fundamental circuits that utilize them. **Students are encouraged to devote as much time as is**

needed to master the material in this course. Most students will need to spend two to three hours outside of class for each hour of lecture.

Students are expected to do regular written homework assignments, and to respond in prose to questions on quizzes and examinations. While most of the work is inherently mathematical, questions on quizzes, tests and homework assignments will require written responses. For each laboratory experiment/project, a written laboratory report will be required. Student research, using libraries and the WWW, is an expected part of laboratory reports.

Assessment:

Consistent with the Formal Assessment Plan of the Department of Electronic Engineering Technology, approved May 6, 1997, a final laboratory project in the last weeks of the course is the primary means of assessing a student's growth and achievement in the course. This project will supplement the traditional means of assessment, including written and oral reports and presentations in lecture and laboratory, homework, quizzes and examinations.

This project will be "documented with a written report detailing all aspects of the project, and will be evaluated by the faculty member teaching the technical course." The graded reports from all projects will be kept by the student as a portfolio of progress. In addition, the Department will maintain a file containing a written evaluation of each project for each student, which shall remain the property of Ward College.

Prerequisites by Topic: EL 243, EL 244, MTH 241, UP 242: small-signal transistor amplifiers used for narrow-band and wide-band linear amplifiers; bandpass filters; detection and rectification; signal conditioning; DC amplifiers; saturated amplifiers; integration and differentiation of sine, square and triangle waveforms; digital concepts include binary words, analog-digital and digital-analog converters.

Grading Criteria:

Course Average Determined by: 3 Tests @ 15% = 45%; Quiz/Homework Avg. = 15%; Final Exam = 15%; In-Lab Performance & Laboratory Reports = 25%.

Course Grade As Follows: 100-93 = A; 92-90 = A-; 89-88 = B+; 87-83=B; 82-80 = B-; 79-78 = C+; 77-73 = C; 72-70 = C-; 69-68 = D+; 67-63 = D; 62-60 = D-; under 60 = F.

Credit By Exam:

Credit for this course may be earned using the University "Credit By Exam" method, *if* the student's transcript does not show that this course was taken in the last five years. Students who elect this option should have substantial knowledge in the subject area, both theoretical and applied, and should expect a comprehensive written exam of two to three hours duration, and a practical exam in the laboratory. The practical exam will consist of completing a laboratory experiment from the list that follows.

Course Syllabus and Time Allocated to Each Topic:

3 Hours - OPERATIONAL AMPLIFIER INTRODUCTION:

Introduction to linear integrated circuits; block diagram, transfer characteristic; use of bi-polar power supplies, saturation, input and output implications, exact and approximate gain with feedback for non-infinite open-loop gain, inverting, non-inverting, and unity-gain source follower modes, concept of virtual short circuit between differential input terminals with unsaturated amplifier.

2 Hours - TRANSISTOR CIRCUIT REVIEW:

DC biasing considerations, current gain, junction voltages, AC small- signal model with h- parameters and Ebers-Moll model. Common-emitter, common-collector circuits.

7 Hours - DIFFERENTIAL AMPLIFIER CIRCUIT:

Basic long-tailed-pair differential amplifier circuit, with resistor emitter impedance; DC circuit analysis, exact and approximate differential gains, common-mode gain, input and output resistances, common-mode rejection ratio. Circuit design, DC and AC. Design of constant-current source, analysis of apparent resistance. Common-mode noise rejection capability, performance analysis of RCA CA3000 differential amplifier IC. Predicting differential amplifier outputs given AC and DC inputs, for differential mode, common mode, and simultaneous differential- and common-mode inputs.

6 Hours - OPERATIONAL AMPLIFIER SPECIFICATIONS:

Definition of terms: input resistance, unity-gain bandwidth, large-signal voltage gain, input offset voltage, input bias current, input offset current, CMRR, output voltage swing, slew-rate, power bandwidth. Use of manufacturers' data sheets for various op-amps. Exact and approximate output offset voltages due to Vio, IB, and Iios. Use of compensating resistor to minimize output offset voltage.

Input resistance for inverting, noninverting, and source follower circuits. Current-to-voltage converter: input impedance, applications. Slew-rate effects on squarewave and sinusoidal input voltages. Internally compensated, decompensated, and uncompensated op-amps. Gain-bandwidth product: Bode-plot analysis, numerical solutions.

5 Hours - OPERATIONAL AMPLIFIER APPLICATIONS:

Electronic thermometer using AD590 temperature to current IC. True differential configuration, un-equal gains differential circuit; summing amplifier, weighted summer, inverting and non-inverting modes. Integrators; analysis and design with sine, square, and triangle input voltages. The practical integrator with reset switch or DC gain stabilization. Differentiators: compensated and uncompensated with sine, square, and triangle waveforms.

3 Hours - DIGITAL TO ANALOG CONVERSION:

Introduction to analog switches. Weighted-summer D/A analysis and design; practical limitations. R-2R current ladder D/A analysis and design. Stepwise transfer characteristics, linearity specifications, monotonicity, resolution.

2 Hours - SAMPLE AND HOLD CIRCUITS:

Acquisition time, droop rate, Nyquist criterion, determining sample rate.

4 Hours - ANALOG TO DIGITAL CONVERTERS:

Speed, complexity, and cost considerations. Flash, parallel, video, or quantizer A/D analysis, decoder logic considerations. Successive approximation method: SAR logic functions, conversion time. Dual-slope integrator method: analysis, lack of need for precise components or long- term stability of clock, noise reduction capability by choice of integration time.

4 Hours - ACTIVE FILTERS:

Review of filter basics, order of response and number of poles concept. Advantages of and limitations of active filters. One op-amp realization of single pole LP, HP, BP filters; analysis and design. Three op-amp notch filter analysis and design. Sallen-Key equal component VCVS filter designs for Bessel, Butterworth, and 1, 2, and 3 dB ripple Chebyshev responses. Bode plots of all filters will be used.

Switched-capacitor digitally-programmed active filter IC (Reticon R5620) in LP, HP, BP, and notch mode; need for clock, digital control of Q and center frequency.

1 Hour - ISOLATION AMPLIFIERS:

Need for isolation amplifiers in medical instrumentation, analysis of typical hybrid IC isolation amplifier.

2 Hours - VOLTAGE REGULATOR INTEGRATED CIRCUITS:

Design of variable voltage regulator and current regulator circuits with National Semiconductor LM317 IC.

Lecture time = 39 hrs; Examinations in class = 3 hours*; Total lecture time = 42 hours

*** Tests use 3 class hours, with the two-hour final exam given during Final Exam Week.
Computer Usage:**
1. Students use the WWW and appropriate search engines to research topics in the course.

2. Students will use PSpice to perform AC and transient analysis on passive and active circuits. Assignments will be given requiring analysis, by hand, of challenging circuits; then, students will use computer analysis tools to solve the same circuits. These assignments will be graded.

Laboratory Projects (including major items of equipment and instrumentation used):

      Equipment Features and Op-Amp Re-familiarization
      Bi-Polar Junction Transistor Differential Amplifier
      Op-Amp DC Parameters
      Slew-Rate, Gain-Bandwidth Product, Output Voltage Swing
      Inverting and Differential Summing Circuits
      Continuously Adjustable Noninverting/Inverting Amplifier Circuit – **Oral Report Required**
      Design of Signal Conditioning Circuit – **Assessment Project**
      Integrators and Differentiators
      Digital to Analog Converters
      Absolute Value Circuit
      Sample and Hold Circuit
      Voltage-Controlled Voltage Source (VCVS) Active Filters
      Note: Due to class interest, pace of lecture and lab classes and duration of the semester, not all topics listed in the syllabus may be covered, and topics not listed above may be covered.

For all laboratory experiments, students will use DC power supply, digital multimeter (voltage, current, resistance), function generator, and dual-trace oscilloscope. Where appropriate, the following instruments will be used: picoammeter, digital oscilloscope.

Oral and Written Communication Requirements: Students write comprehensive laboratory reports for every laboratory project. These are done individually. Oral communication occurs in lecture and

laboratory, using a Socratic technique, in which students must ask questions and respond to questions

using professional vocabulary and proper English. Students are expected to do regular written homework assignments, and to respond in prose to questions on quizzes and examinations. While most of the work is inherently mathematical, questions on quizzes, tests and homework assignments will require written responses.

Calculus Usage: A co-requisite for this course is MTH 241, integral calculus (with a prerequisite of MTH 232, differential calculus). Concepts such as **i = C(dv/dt)** are used in the presentation of and derivation of equations for slew rate, op-amp based differentiators and integrators. Calculus concepts are also important for explaining active filter response and the quantitative aspects of decoupling capacitors.

Library Usage: Students are told how to use the University library to obtain technical information, and are taught how to use the worldwide web to obtain supplemental information, with my blessing, encouragement and assistance. This supplemental information is used by the better students to augment their laboratory reports.