The Hong Kong University of Science and Technology

ELEC3400 Course Syllabus

[Introduction to Integrated Circuits and Systems]

[ELEC3400 (L1)]

[4 Credits]

[ELEC 2200 and ELEC 2400]

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Course Description

[Overview of integrated circuits (IC) and their applications. Basic operating principles of diode, bipolar and MOSFET will be covered. Fundamental analog IC design: dc biasing, small-signal transistor models, single-transistor amplifier, differential amplifier, current mirrors, and active loads will be covered. High-frequency small-signal analysis of amplifiers will be studied.]

Intended Learning Outcomes (ILOs)

[This course aims to provide students with a foundational understanding of the emergence, design, functionality, and usefulness of integrated circuits.]

Key learning goals include:

- **ILO1:** Understanding the Basics:
  - Semiconductors
  - Diodes and transistors
- **ILO2:** Semiconductor Usage as Circuit Components I:
  - Diode as a One-Way Switch:
    - Study how rectifiers, made possible by diodes (one-way switches), convert AC to DC and enable signal detection.
    - Create logic functions using diodes.
- **ILO2:** Semiconductor Usage as Circuit Components II:
  - Transistors as Amplifiers:
    - Explore single-stage and multi-stage amplifiers, including differential amplifiers, to understand signal amplification.
- **ILO3**: Simulation Skills:
  - Gain practical experience using Cadence Virtuoso for circuit simulations.
- **ILO4**: Practical Implementation:
  - Replace the black box of an audio amplifier with real transistor-level simulations and apply this knowledge in a simple AM radio project.
  - Real-World Application:

- Be exposed to using the 65nm CMOS 180nm BICMOS Process Design Kit (PDK) to work with real transistor models for both MOS and BJT.

- **ILO5**: Resources:
  - Access to a reference book and McGraw-Hill software for additional learning and support.

This comprehensive approach helps students connect theory with practical applications in integrated circuit design.]

Assessment and Grading

This course will be assessed using criterion-referencing and grades will not be assigned using a curve. Detailed rubrics for each assignment are provided below, outlining the criteria used for evaluation.

Assessments:

[List specific assessed tasks, exams, quizzes, their weightage, and due dates; perhaps, add a summary table as below, to precede the details for each assessment.]

Assessment Task	Contribution to Overall Course grade (%)	Due date
Final Exam	30%	19/12/2024 *
Midterm Exam	25%	17/10/2024 *
Homework	15%	16/9 to 9/12/2024 *
Lab Reports	15%	26/9 to 5/12/2024*
Quiz	10%	3/10 to 21/11/2024 *
Tutorial Attendance	5%	11/9 to 11/12/2024

* Assessment marks for individual assessed tasks will be released within two weeks of the due date.

Mapping of Course ILOs to Assessment Tasks

Assessed Task	Mapped ILOs	Explanation
[Homework 1]	[ILO1, ILO2]	[This task recaps students' understanding of the ideal op-amps and their utilization in creating useful circuits. Later, replace this "mysterious box" with transistors that we learn in this course. (ILO1, ILO2)]
[Homework 2]	[ILO1, ILO2, ILO3, ILO5]	[Examine students' understanding of diode operation basics (ILO1, ILO2). They will deal with diodes as one directional switches in DC applications, which is the fundamental for digital circuits. Additionally, they will solve questions about diode usage in full-wave and half-wave rectifiers to solidify their understanding of the circuit-level operation of the diode (ILO2). Students will verify their

		answers through Cadence simulation of those circuits, where the diode is replaced by a first-order model (ILO3). They will have access to the McGraw-Hill book and software, which includes various examples for further learning (ILO5).]
[Homework 3]	[ILO1, ILO2, ILO4]	[Examine students' understanding of bipolar transistors (ILO1, ILO2). They are asked about biasing, which differs from concepts covered in their linear circuit courses. They have learned about the exponential relationship between the base-emitter voltage and collector current of a BJT transistor in this course's lecture. Through this homework exercise, they will reinforce their ability to analyze transistor circuits and learn how to control the current and voltage of bipolar transistors using resistors in appropriately selected configurations, despite the presence of the exponential relationship (ILO4).]
[Homework 4]	[ILO1, ILO2, ILO4]	[Assess students' understanding of bipolar transistors in AC (ILO1, ILO2). This assignment, combined with Homework 3, helps students address the non-linear behavior of transistors by separating that nonlinearity into two distinct modes: DC large signal and AC small signal. This understanding enables them to analyze useful circuits that serve as the foundation for more complex designs in today's microelectronics. (ILO2). The concepts of small signal gain, input and output resistance, and different configurations for both MOS and BJT covered here are sufficient to enable students to design a multi-stage amplifier with specific gain and load requirements (ILO4).]
[Homework 5]	[ILO1, ILO2, ILO4]	[They analyze a fairly complex multi-stage amplifier by breaking it down into common source, common emitter, and common collector stages, the behavior of which they have already learned. They calculate the overall gain and input resistance. Additionally, they are assessed on their understanding of differential amplifiers, which are essential components for mitigating coupled

		noise from the surroundings. (ILO1, ILO2, ILO4).]
[Lab 1]	[ILO3, ILO4]	This lab demonstrates one of the uses of integrated circuits in our daily lives by allowing students to assemble a simple radio to listen to music (ILO4). It reinforces the practical application of diodes and amplifiers while highlighting the relevance of integrated circuits in everyday technology. Additionally, students will learn basic measurement techniques, troubleshooting skills, and important tips for using breadboards to build sensitive analog circuits (ILO3).
[Lab 2]	[ILO1, ILO2, ILO3]	The main purpose of this lab session is to help students understand the characteristics of bipolar junction transistors (BJTs) (ILO1, ILO2). By simulating the I-V curves of BJTs and deriving small-signal parameters, students can relate to lecture content about BJT characteristics and BJT-based amplifiers. Additionally, students will learn to use EDA tools such as Cadence Virtuoso to conduct DC and AC simulations (ILO3).
[Lab 3]	[ILO1, ILO3, ILO4]	In Lab 1, students assembled an amplitude-modulation (AM) radio receiver using breadboards and discrete devices, gaining hands-on experience with diodes and amplifiers (ILO4). For the Lab 3, they will revisit the AM radio receiver, this time building and simulating it in Cadence using a transistor-level model for the audio amplifier (ILO3). Students can examine the voltage and current at each node during operation. The purpose of this project is to give students a sense of being integrated circuit designers (ILO1).
[Midterm]	[ILO1, ILO2, ILO4]	The mid-term exam is open-book. Electronic devices can be used without network connections. It examined students' understanding of the theory, useful circuit components, and practical implementations. Q1: The useful analog building block of operational amplifier (ILO2). Q2: Diode as a one directional switch; they assume the operation region and examine their assumptions

		through using Kirchhoff's Voltage Law (KVL) and Kirchhoff's Current Law (KCL) (ILO1, ILO2). Q3: DC biasing of the bipolar transistor using a four-resistor configuration and its sensitivity to process variations. (ILO1, ILO2, ILO4).
[Final Examination]	[ILO1, ILO2]	The final exam is open-book. Electronic devices can be used without network connections. It examined students' understanding of the theory. Q1: BJT physics and operation principles (ILO1). Q2: MOSFET operation regions and squared law formula (ILO1). Q3: Single-stage common emitter amplifier input-output relationship (ILO2). Q4: Multi-stage amplifier concepts (ILO2). Q5: Differential and common mode operations (ILO2). Q6: Comparing different topologies of a single-stage amplifier in terms of gain and output resistance (ILO2).

Grading Rubrics

[Detailed rubrics for each assignment will be provided. These rubrics clearly outline the criteria used for evaluation. Students can refer to these rubrics to understand how their work will be assessed.]

Final Grade Descriptors:

[As appropriate to the course and aligned with university standards]

Grades	Short Description	Elaboration on subject grading description
A	Excellent Performance	[Demonstrates a deep understanding of the material. They are eager and dedicated to furthering their knowledge. Their performance in multi-dimensional assessments of this course is significantly above average.]
B	Good Performance	[Displays a good understanding of the material and shows enthusiasm for further learning. Their performance in multi-dimensional assessments of this course is above average, although some assignments reflect good work rather than excellence.]
C	Satisfactory Performance	[Has a basic understanding of core subject matter and can tackle familiar problems. Demonstrates effort in pursuing broadly defined learning goals. Their performance in most assessments is average or slightly above.]

D	Marginal Pass	[Benefits from the course and demonstrates the potential for growth in the discipline. Their performance in assessments is generally average.]
F	Fail	[Fails to meet the basic requirements for professional practice or development in the discipline. Their performance in assignments is significantly below average.]

Course AI Policy

[Students may use generative AI tools for assessment tasks, except for final exams. For certain homework assignments, students are encouraged to use ChatGPT thoughtfully.]

Communication and Feedback

Assessment marks for individual assessed tasks will be communicated via Canvas within two weeks of submission. Feedback on assignments will include [specific details, e.g., strengths, areas for improvement]. Students who have further questions about the feedback including marks should consult the instructor within five working days after the feedback is received.

Resubmission Policy

[Students are not allowed to resubmit after the deadlines. Students with late submission lose marks.]

Required Texts and Materials

[R. Jaeger and T. Blalock, Microelectronic Circuit Design, 5th Edition, McGraw Hill.

A. S. Sedra and K. C. Smith, Microelectronic Circuits, 7th Edition]

Academic Integrity

Students are expected to adhere to the university's academic integrity policy. Students are expected to uphold HKUST's Academic Honor Code and to maintain the highest standards of academic integrity. The University has zero tolerance of academic misconduct. Please refer to Academic Integrity | HKUST – Academic Registry for the University's definition of plagiarism and ways to avoid cheating and plagiarism.

[Optional] Additional Resources

[https://connect.edu.mheducation.com/]