ECE 636: Advanced Analog Integrated Circuits (Fall 2020)

Course Content: This course covers the design of complementary metal-oxide-semiconductor (CMOS) analog integrated circuits at the transistor level, with an emphasis on the analysis and design of single-stage and multi-stage amplifiers. Related topics including device modeling, biasing, stability, and noise will be presented. In addition, an introduction to higher-level analog and mixed analog/digital systems, such as switched-capacitor circuits, will be covered. Computer-aided design (CAD) software for circuit simulation will be used throughout the course.

Instructor:

Peter M. Levine, Ph.D., P.Eng.
Associate Professor, Department of Electrical and Computer Engineering
Email: pmlevine@uwaterloo.ca

Lecture Delivery Format and Schedule:

- All lectures will be delivered online, either synchronously (live) or asynchronously, depending on the time zones of enrolled students.
- The delivery format and schedule will be determined during the first week of class.
- In case the format is live, we will likely deviate from the [redacted] time slot shown on the Schedule of Classes for Graduate Students website (http://www.adm.uwaterloo.ca/infocour/CIR/SA/grad.html).

Course Topics:

- MOSFET physical characteristics, operating regions, and performance limits
- Systematic design of single-stage, two-stage, and three-stage amplifiers
- Current mirrors and amplifier biasing circuits
- Feedback, stability, and settling
- Distortion
- Fully-differential amplifiers and common-mode feedback (CMFB) circuits
- Noise modeling and analysis
- Mismatch analysis
- Introduction to switched-capacitor (SC) circuits
- Bandgap references

Background and Pre-requisites:

- Required: One of ECE 242, ECE 340, NE 344, BME 489, or equivalent. These undergraduate courses cover cascode amplifiers, current mirrors, MOS/BJT differential and multi-stage amplifiers, frequency response, feedback, etc. See chapters 7 to 11 of Sedra and Smith, 7th ed. for a full list of topics.
- Required: An undergraduate-level course in (1) signals and systems and (2) linear control systems.

Evaluation (Tentative):

Mini-Projects and Graded Review Problem Set:	15% (all equally weighted)
Final Project:	15%
Midterm exam:	20%
Final exam:	50%

Mini-Projects and Graded Review Problem Set: There will be three or four graded mini-projects which will normally include circuit design problems and involve the use of CAD software. There will also be a graded problem set meant as a review of your pre-requisite knowledge. Only a subset of the problems in each mini-project and the review problem set will be graded. Partial solutions to some problems may be released.

Non-graded Problem Sets: Pencil-and-paper-style problem sets will be assigned periodically throughout the course. These are not graded and do not have to be submitted. Partial solutions to some problems in each set may be released.

Midterm Exam: A midterm exam will be given in weeks 6−8 of the term (to be determined). Exam conditions will be provided at a later time.

Final Exam: There will be a final exam given during the regular Fall-term exam period. Exam conditions will be provided at a later time. You will be responsible for all material covered in the course.

Course Website: This is available through LEARN (http://learn.uwaterloo.ca). Lecture slides, problem sets, etc. will be posted here.

CAD Software: We will use industry-standard circuit simulation software from Cadence (Virtuoso Schematic Editor, Virtuoso Analog Design Environment, and Spectre). No prior experience with Cadence software is required. However, it is expected that you are familiar with math processing software such as MATLAB or Excel.

Project Description: The project will be assigned by the instructor and will involve transistor-level schematic design and simulation of an analog system (e.g., first stage of a pipelined ADC, sample and hold amplifier, etc.) with various performance specifications. Students will complete the project individually.

Reference Texts:

- P. R. Gray, P. J. Hurst, S. H. Lewis, and R. G. Meyer, *Analysis and Design of Analog Integrated Circuits*, 5th ed., Hoboken, NJ: Wiley, 2009.
- B. Razavi, *Design of Analog CMOS Integrated Circuits*, New York: McGraw-Hill, 2001 (1st ed.) or 2016 (2nd ed.).
- T. Chan Carusone, D. A. Johns, and K. W. Martin, *Analog Integrated Circuit Design*, 2nd ed., Hoboken, NJ: Wiley, 2012.
- R. J. Baker, *CMOS: Circuit Design, Layout, and Simulation*, 3rd ed., Hoboken, NJ: Wiley, 2010. (Second edition available online through University of Waterloo Libraries website.)
- W. M. C. Sansen, *Analog Design Essentials*, Dordrecht, The Netherlands: Springer, 2006 (Available online through University of Waterloo Libraries website.)
- A. S. Sedra and K. C. Smith, *Microelectronic Circuits*, 7th ed., New York: Oxford University Press, 2015.
- Y. Tsividis, *Mixed Analog-Digital VLSI Devices and Technology*, Singapore: World Scientific, 2002.