CONCORDIA UNIVERSITY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ELEC 423/6051 Introduction to Analog VLSI
Fall 2014

Course Outline

INSTRUCTOR:

Glenn Cowan, Associate Professor, Electrical and Computer Engineering
Office: EV5.167, Telephone: 848-2424 Ext. 4108
Office Hours: Monday and Thursday, noon to 1:30 pm.

LECTURE:

Monday/Wednesday 10:15 – 11:30 AM, MB-S2.115

LABORATORY:

Friday 14:45 – 17:30. Scheduled for Ugrads only.

USEFUL TEXTBOOKS WORTH CONSULTING:

- R. J. Baker, "CMOS Circuit Design, Layout, and Simulation," revised 2nd edition, Wiley, 2008.
- P. R. Gray, P. J. Hurst, S. H. Lewis, R. G. Meyer, "Analysis and design of analog integrated circuits," 4th edition, Wiley, 2001.
- D. Johns and K. Martin, "Analog Integrated Circuit Design," Wiley, 1997.
- B. Razavi, "Design of Analog CMOS Integrated Circuits," McGraw-Hill, 2001.

CALENDAR DESCRIPTION

ELEC 423 ***Introduction to Analog VLSI*** (4 credits)
Prerequisite: ELEC 311. CMOS transistor layout considerations, design rules, circuit extraction. MOSFET modelling, I-V equations, AC equivalent circuits for high-frequency operation, computer-based simulation. Analysis and design of small-scale integrated circuit building blocks including MOS switch, active resistor, current source, current mirror, voltage amplifiers, voltage-reference circuits, multipliers. Analysis and design of medium-scale integrated circuit building blocks including op-amps, fully-differential op-amp and common mode feedback circuits, transconductance amplifiers, transimpedance amplifiers, comparators. Noise analysis. Mismatch analysis and modeling, offset removal techniques. Analog VLSI system examples. Lectures: three hours per week. Laboratory: 30 hours total.

OVERALL COURSE OBJECTIVES:

The objective of the course is for students to gain analysis and design skills necessary for Analog IC design, either in industry or academia. The syllabus, assignments, project, and tests have been developed based on the analysis and design problems analog IC designers face.

By the end of the term, students should be able to:

1. Demonstrate an understanding of MOS terminal characteristics and capacitive effects.
2. Create integrated circuit layouts showing an awareness of the underlying process technology and layout parasitics as well as their impact on circuit performance.
3. Show a working knowledge of and an ability to analyze basic gain stages, current mirrors, and active loads. Students should be able to make choices among these building blocks.
4. Select the length, width, and bias level of transistors with an awareness of biasing trade-offs associated with the transistor's level of inversion.

5. Analyze a circuit to determine input and output referred noise power spectral density. Students should also be able to propose design modifications to reduce noise levels and be able to determine which transistors contribute most to noise levels.
6. Analyze a circuit to determine input and output referred offsets. Students should also be able to propose design modifications to reduce offsets and be able to determine which transistors contribute most to offsets.
7. Analyze various single-stage and two-stage opamp circuits to determine gain (differential and common-mode), frequency response, output resistance, short-circuit transconductance, input common-mode range, and output signal range. Students should be able to compensate an opamp for closed loop stability, given a certain feedback factor.
8. Compute an opamp's required dc gain, slew rate, and unity-gain frequency based on the required closed-loop settling dynamics of a sample-and-hold system.
9. Recognize situations that require common-mode feedback and propose a *suitable* common-mode feedback scheme comprised of a common-mode detector, an amplifier, and a control mechanism. Students should also make choices that lead to a stable common-mode feedback loop with loop dynamics similar to the differential-mode loop.
10. Apply the Barkhausen criteria to a circuit or system in order to determine if it is likely to oscillate. Students should be able to analyze various ring-oscillators and *LC* oscillators to compute the required gain for oscillation and the approximate frequency of oscillation.
11. Show awareness of global process variation and its effect on circuit performance.
12. Analyze basic voltage and current reference circuits

PREREQUISITE MATERIAL:

This course assumes that students have a basic command of the following topics:

Background Topics	Sections from Microelectronics 6th Ed. (Sedra and Smith)
DC, square-law operation of MOSFETs	5.1, 5.2
Low-frequency small-signal models of MOSFETs	5.5
AC and DC analysis of single transistor amplifiers with resistive loads	5.3, 5.6, 5.7, 5.8
Analysis of circuits with operational amplifiers	2.1-2.3

TENTATIVE LECTURE SCHEDULE: Please note that this is tentative.

Lecture	**Date**	**Lecture Topics**	**Lab Topics**
1	Sept 3rd	Introduction of Course, student information sheet Review of MOS transistor operation	Schematic tutorial, dc sweeps of NMOS and PMOS devices
2	Sept 8th	Review of DC and AC analysis of MOS transistor circuits	AC/Transient analysis
3	Sept 10th	Weak Inversion, body effect, capacitors, differential pairs	
4	Sept 15th	Bode plots, active loads, current mirrors, cascodes	Current mirrors, active loads
5	Sept 17th		
6	Sept 22nd	Process Technology and layout considerations	Layout tutorial
7	Sept 24th	Noise: signal descriptions, models, analysis, design considerations	
8	Sept 29th	Mismatch: Causes, models, analysis, design considerations	Noise analysis
9	Oct 1st		

10	Oct 6th	Operational amplifier basics	Mismatch
11	Oct 8th	Project overview	
12	Oct 15th	Operational amplifiers	
13	Oct 20th	**Midterm Exam**	**Project (broken down into weekly targets)**
14	Oct 22nd	Advanced opamps.	
15	Oct 27th		
16	Oct 29th	Common-mode feedback	
17	Nov 3rd		
18	Nov 5th	Oscillators	
19	Nov 10th	References	
20	Nov 12th		
21	Nov 17th	Design in the presence of global process variation	
22	Nov 19th		
23	Nov 24th	Design in very-low supply voltages.	
24	Nov 26th		
25	Dec 1st	**Project due in class.**	No scheduled Lab
26	Dec 2nd	(Tuesday. Make up for class on Thanksgiving)	

ASSIGNMENTS:
A combination of paper/pencil and CAD based assignments will be given. These will reinforce concepts developed in class and prepare students for the project.

PROJECT:
A design project will be given in the second half of the semester. Due Mon, Dec 1st.

GRADING SCHEME:

	Undergrad Students	**Graduate Students**
Assignments/Labs	15%	15%
Midterm test	15%	15%
Project	20%	30%
Final examination	50%	40%
Total:	**100%**	**100%**

Please note that the Midterm exam will count. No alternate scheme in which the midterm is not counted will be offered. During the midterm test and the final exam, only one of the two ENCS-approved calculators (CASIO FX-300MS and SHARP EL-531) will be allowed.

Assignments, labs, and the project must be accompanied by a signed copy of ENCS's Expectations of Originality form.
See: http://www.encs.concordia.ca/current-students/forms-and-procedures/expectation-of-originality/

NOTES ON PLAGIARISM (Source: The Academic Integrity Website: http://provost.concordia.ca/academicintegrity/plagiarism/)**:**

The most common offense under the Academic Code of Conduct is plagiarism which the Code defines as "the presentation of the work of another person as one's own or without proper acknowledgement." This could be material copied word for word from books, journals, internet sites, professor's course notes, etc. It could be material that is paraphrased but closely resembles the original source. It could be the work of a fellow student, for example, an answer on a quiz, data for a lab report, a paper or assignment completed by another student. It might be a paper purchased through one of the many available sources. Plagiarism does not refer to words

alone - it can also refer to copying images, graphs, tables, and ideas. “Presentation” is not limited to written work. It also includes oral presentations, computer assignments and artistic works. Finally, if you translate the work of another person into French or English and do not cite the source, this is also plagiarism.

In Simple Words:
Do not copy, paraphrase or translate anything from anywhere without saying where you obtained it!

LIST OF SERVICES
Concordia Counseling and Development offers career services, psychological services, student learning services, etc.
http://cdev.concordia.ca/

The Concordia Library Citation and Style Guides:
http://library.concordia.ca/help/howto/citations.html

Advocacy and Support Services
http://supportservices.concordia.ca/

Student Transition Centre
http://stc.concordia.ca/

New Student Program
http://newstudent.concordia.ca/

Access Centre for Students with Disabilities
http://supportservices.concordia.ca/disabilities/

Student Success Centre
http://studentsuccess.concordia.ca/

The Academic Integrity Website
http://provost.concordia.ca/academicintegrity/

Financial Aid & Awards
http://web2.concordia.ca/financialaid/

Health Services
http://www-health.concordia.ca/