ENG EC580 – Analog VLSI Circuit Design

Term: Fall 2020

Lectures: Mon-Wed 4:30 – 6:15 pm in EPC 206

Number of Credits: 4

Pre-requisites: ENG EC 412 or equivalents are pre-requisities for this course.
Please talk to us if you have any questions about pre-requisities.

Course Objectives
"The world we live in is analog. We are analog. Any inputs we can perceive are analog. For example, sounds are analog signals; they are continuous time and continuous value. Our ears listen to analog signals and we speak with analog signals. Images, pictures, and video are all analog at the source and our eyes are analog sensors. Measuring our heartbeat, tracking our activity, all requires processing analog sensor information.

Computers are digital. Information is represented with discrete time and amplitude quantized signals using digital bits. Such representation lends itself to efficient processing and long-term storage of signals and information. But information and signals come from the physical world and need to move back into the physical world for us to perceive them. No matter how "digital" our electronic devices get, they always require interfaces that translate signals from the physical world into the digital world of electronics." "The World is Analog"[P. Kinget, Circuit Cellar #292, 11/2014]

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

- Analyze and design analog CMOS integrated circuits such as current mirrors, operational amplifiers, and switched-capacitor circuits.
- Build an intuition for analog design trade-offs.

Staff Information

Instructor Name:	Rabia Yazicigil Kirby
E-mail address:	rty@bu.edu – Include EC 580 in the subject line
Office hours:	Zoom Meeting, Monday 1:30 pm to 2:30 pm or by appointment

Course Learning Goals:
By taking this course, students should be able to understand:

(1) MOS DC operation in weak, moderate, strong inversion.
(2) MOS AC small signal models.
(3) Basic transistor stages:
Common gate, common source, common drain, current mirrors, and cascodes.
(4) Single-ended and fully-differential operational amplifier analysis and design:
Telescopic, folded cascode, two-stage OTA, common-mode feedback.
(5) Application: Switched-capacitor 2x amplifier
Time-domain settling, switch design, and non-idealities.
(6) Stability and frequency compensation techniques in differential and common mode.
(7) Noise in circuits and low-noise design techniques.
(8) Device mismatch and design techniques to minimize effects of mismatch.
(9) Temperature- and supply-independent biasing.

Course Resources

- **Text Book (strongly recommended):**
  Design of Analog CMOS Integrated Circuits, Second Edition. Behzad Razavi, McGraw-Hill Education. Available at Barnes & Noble. Used as the textbook reference in the tentative schedule.

- **Text Books (optional):**
  Analog Integrated Circuit Design, Second Edition. Tony Chan Carusone, David Johns, Kenneth Martin, John Wiley & Sons. Available at Barnes & Noble.

  CMOS Analog Circuit Design, Third Edition. Phillip E. Allen, Douglas R. Holberg, Oxford University Press. Available at Barnes & Noble.

- Announcements, course material, tutorials, and other useful links will be posted on Blackboard (http://learn.bu.edu/).

Evaluation

Grading criterion:	Midterm Exam - 30%, Final Exam - 35%, Homework - 25%, Participation - 10%
Homework:	Homework assignments are to be submitted before the beginning of the class on the date specified. You can discuss your work in abstract with other students in the class, but you should write-up the solutions on your own.
Exams:	There will be one midterm exam and one final exam.
Participation:	Active discussion participation via Zoom or in person during lectures.

Course Policy

- **Homework:** The homework assignments must be the result of your individual work. You may discuss the contents and general approach to a problem with your classmates but not the detailed solution. You are expected to formulate your approach and write the solutions of homework problems by yourself. Copying the solution and/or answer from another student is considered cheating. Two identical homework with same mistakes are considered cheating. **No extensions on homework will be provided. Homework received up to 24 hours late will receive maximum 50% credit. Homework received beyond 24 hours late will not be accepted.**

- **Makeup exams:** Makeup exams will be provided if the student takes prior permission from the instructor. Emergencies will be dealt on a case-by-case basis. Note that oversleeping, being not ready, overload due to projects or coursework in other classes are not valid excuses for requesting a makeup exam.

- **Exam/Homework grade discussion:** Grade discussion/corrections should be done within one week after the graded exam or homework is distributed. No grade changes will be made after one week, or after the last day of class.

- **I and W grades:** As per University policy.

- **Honor Code:** It is expected that Boston University's Honor Code will be followed in all matters relating to this course. If you are found cheating on homework or examinations, you will be brought up on charges before the **Student Academic Conduct Committee** whose punishment may include suspension from the University without the right to transfer credits for courses taken elsewhere.

- Students are responsible for understanding the University's Honor Code policy and must make proper use of citations of sources for writing papers, creating, presenting, and performing their work, taking examinations, and doing research.

- Full text of the honor code policy and fundamental standard: Boston University's Academic Conduct Code

- **COVID 19 & BU Community Health Expectations:**
  Masks are required and face coverings must be worn over the mouth and nose at all times when in public spaces on campus, including classrooms. Students should be prepared to show proof that they are compliant with health attestations and testing in order to attend class. All students are expected to follow all university guidelines with respect to daily symptom checks, testing, social distancing, and mask wearing when they leave their dorm or home. For a detailed description of official BU policies regarding COVID, please visit: *http://www.bu.edu/dos/policies/lifebook/covid-19-policies-for-students/*

- **Inclusion:** I consider this classroom to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

- **Accommodations for Students with Documented Disabilities**: If you are a student with a disability or believe you might have a disability that requires accommodations, requests for accommodations must be made in a timely fashion to Disability & Access Services, 25 Buick St, Suite 300, Boston, MA 02215; 617-353-3658 (Voice/TTY). Students seeking academic accommodations must submit appropriate medical documentation and comply with the established policies and procedures *http://www.bu.edu/disability/accommodations/*

Tentative Schedule for EC580 – Lectures, Homework, and Exams					
Lec #	Date	Topic Description	Text Ref	Out	Due
1	9/2	Introduction, MOSFET Qualitative View, DC Model	Chapter 1, 2		
2	9/9	MOSFET DC and Small-Signal Modeling	Chapter 2		
3	9/14	Single-Stage Amplifiers - I	Chapter 3	Hw1	
4	9/16	Single-Stage Amplifiers - II	Chapter 3		
5	9/21	Current Mirrors and Biasing Techniques - I	Chapter 5		
6	9/23	Current Mirrors and Biasing Techniques - II	Chapter 5		
7	9/28	Differential Amplifiers - I	Chapter 4	Hw2	Hw1
8	9/30	Differential Amplifiers - II	Chapter 4		
9	10/5	Operational Amplifiers - I	Chapter 9		
10	10/7	Operational Amplifiers – II	Chapter 9	Hw3	Hw2
	10/12	Columbus Day Holiday			
11	10/13	Substitute Monday Schedule of Classes: Feedback - I	Chapter 8		

12	10/14	Feedback - II	Chapter 8		
13	10/19	Switched-Capacitor Circuit Design - I	Chapter 13		
14	10/21	Switched-Capacitor Circuit Design - II	Chapter 13	Hw4	Hw3
15	10/26	Frequency Response & Compensation - I	Chapter 6, 10		
16	10/28	Frequency Response & Compensation - II	Chapter 6, 10		
17	11/2	Frequency Response & Compensation - III	Chapter 6, 10		Hw4
18	11/4	Midterm Exam			
19	11/9	Noise - I	Chapter 7	Hw5	
20	11/11	Noise - II	Chapter 7		
21	11/16	Noise - III	Chapter 7		
22	11/18	Nonlinearity and Mismatch - I	Chapter 14		
23	11/23	Nonlinearity and Mismatch - II	Chapter 14		
	11/25	Thanksgiving Recess			
24	11/30	Supply and Temperature Independent Biasing - I	Chapter 12		Hw5
25	12/2	Supply and Temperature Independent Biasing - II	Chapter 12		
26	12/7	Supply and Temperature Independent Biasing - III	Chapter 12		
27	12/9	Review Session			
	TBD	Final Exam			