CMOS Analog IC Design

Course Duration: 90 hours (45 hours lectures + 45 hours labs)

CAD Tools: Full-custom design tools from any major EDA vendor (Cadence, Synopsys, Mentor)

Instructor: Dr. Hesham Omran (Email: hesham.omran@eng.asu.edu.eg)

Course Prerequisites:

- Basic undergraduate mathematics: complex numbers, basic differentiation and integration, etc.
- Basic undergraduate circuit analysis course: resistors, capacitors, inductors, Ohm's law, KVL, KCL, nodal analysis, mesh analysis, superposition, Norton and Thevenin equivalents, simple RC circuits.
- Basic undergraduate semiconductor physics course: doping, n-type and p-type semiconductors, holes, electrons, diffusion and drift currents, pn-junction operation and models.
- Basic undergraduate electronic circuits course: transistor models, dc biasing, small signal analysis, basic amplifiers (common-source, common-gate, common-drain), op-amp applications (inverting amplifier, non-inverting amplifier, integrator, differentiator, etc.).

Course Description:

- This course covers core topics in analog IC design, and prepares the student for real-life design of complex analog/mixed-signal blocks. The course focuses on CMOS circuits because CMOS is the prevalent technology in the integrated circuits market. Both analysis and design are covered in this course.
- The course contains a strong hands-on component. Each training day is composed of lectures and labs. During the labs, the students will be trained to use industry-standard CAD tools to analyze and design analog CMOS circuits.
- The course applies modern teaching methods such as the flipped classroom model and interactive discussions. You will be challenged with interview questions and you will be given practical tips and hints. Your progress will be continuously assessed using daily quizzes and you will be given real feedback on your work.
- This course fills the following gaps in conventional undergraduate/graduate courses:
    1. Focusing on analysis by inspection skills and developing the "designer's intuition" which is necessary to be a real designer
    2. Verifying hand-analysis and theoretical concepts using extensive circuit simulations
    3. Using industry standard CAD tools to design and verify analog CMOS circuits
    4. Design of analog CMOS circuits to achieve required specifications using state-of-the-art design methodologies

Course Website:

https://www.master-micro.com/mastering-microelectronics/courses/analog-ic-design

Course Plan:

Day	Lecture (3h/day)	Lab (3h/day)
1	• **Lecture 01: Introduction** • **Lecture 02: Circuits and systems review** • **Lecture 03: Semiconductors review**	• **Lab 01 (Part 1): Basic simulations of RC circuit** Transient simulation, AC simulation, pole-zero simulation, parametric sweeps, calculator and expressions
2	• **Lecture 04: MOSFET large signal model** • **Lecture 05: MOSFET small signal model**	• **Lab 01 (Part 2): MOSFET long channel and short channel characteristics** DC sweeps, ID-VGS, gm-VGS, ID-VDS, gm and gds in triode and saturation
3	• **Lecture 06: Single-stage CMOS amplifiers** • **Lecture 07: Cascode amplifiers**	• **Lab 02: Common-source amplifier** Creating design charts, OP simulation, gain non-linearity, maximum attainable gain, gain linearization
4	• **Lecture 08: Frequency response (1)** • **Lecture 09: Frequency response (2)**	• **Lab 03: Cascode amplifier** Cascode with active load, cascode with resistive load, effect of cascode on gain, BW, and GBW
5	• **Lecture 10: Current mirrors**	• **Lab 04: Frequency response of CD buffer** Complex poles, frequency-domain peaking, time-domain ringing, inductive rise
6	• **Lecture 11: Differential amplifier**	• **Lab 05: Current mirrors** Simple current mirror, cascode current mirror, wide-swing (low-compliance) current mirror
7	• **Lecture 12: Five-transistor OTA** • **Lecture 13: Gm/ID design methodology**	• **Lab 06: Differential amplifier** Differential gain, common-mode gain, CMRR, common-mode input range, large signal operation
8	• **Lecture 14: OTA design example**	• **Lab 07: OTA design** Gm/ID design charts, design procedure of five-transistor OTA, open-loop simulation, closed-loop simulation
9	• **Lecture 15: Negative feedback**	
10	• **Lecture 16: OTA stability and compensation**	• **Lab 08: Negative feedback** Behavioral modeling, hierarchy editor, effect of feedback on gain/BW/GBW, open-loop gain, closed-loop gain, loop-gain, gain desensitization
11	• **Lecture 17: Noise (1)** • **Lecture 18: Noise (2)**	• **Lab 09 (Mini Project 01): Two-stage Miller OTA** Design procedure of two-stage Miller OTA, frequency compensation, RHP zero, verification
12	• **Lecture 19: OTA topologies**	
13	• **Lecture 20: Common-mode feedback (CMFB)**	• **Lab 10: Noise simulation** AC noise simulation, transient noise simulation, noise in five-transistor OTA
14	• **Lecture 21: Slew rate and PSRR** • **Lecture 22: Variability and mismatch**	• **Lab 11 (Mini Project 02): Fully differential folded cascode OTA** Design of folded cascode OTA with capacitive feedback, behavioral and actual CMFB network
15	• **Lecture 23: Biasing and references**	

What students say about this course:

“One of the greatest courses I have taken since I started college.”

"I recommend this course to every student in Electronics and Communication department."

"في اللحظة التي انتهى فيها شعرت وكأني أريد الزمن أن يعود لأول يوم فيه وأعيد هذه التجربة الماتعة التي أحزنني بحق انتهاؤها.. فحقًّا سأشتاق لكل شيء.. لقد تعلمت الكثير.. إنها تجربة مختلفة من حيث المحتوى العلمي والتطبيق العملي وأسلوب التدريس وود ولطف وشغف واحترافية الدكتور ومساعديه ما يجعلك تعشق المجال بالرغم مما تواجه فيه من صعوبات.. لقد أضاف لي الكثير وفتح لي آفاقًا أوسع ورسّخ ما تعلمته من قبل ووضّح ما كان غامضًا ويسّر ما كان عسير الفهم فيه.. فمن أفضل ما فيه هو الفهم العميق للأساسيات التي يبنى عليها كل شيء.. بالإضافة إلى منهجية التصميم التي يقدمها مما سيساعد كثيرا في العمل الإبداعي في المجال.. لقد كان أمتع صيف قضيته في حياتي.."

“This course is so useful and powerful and also nearly equivalent to EE214B course of Stanford university.”

“It was an awesome course. It has a lot of interesting topics and a lot of knowledge and experience. The staff was amazing and the videos by Dr Hesham were excellent. The whole course exceeded my expectations. I enjoyed the design and the labs and everything about the course.”

“I have enjoyed this course very much, the topics were very interesting, the content of the course is rich and very well organized, the lecturer is excellent, and I liked the continuous assessment of the students.”

“Reports and quizzes in this course play an important role in keeping the learners always up with the course.”

“The course content is enough to have a perfect base for future study. The atmosphere in the course is inspiring.”

“A great experience that I recommend for anyone interested to learn more about analog IC design. This training covers essential topics in analog IC design from both the analysis and design perspectives. Also, these topics are discussed in a simple and straightforward way. Moreover, the teacher and the TAs are so friendly and helpful.”

“The instructors were perfect in delivering information. Labs are so enjoyable.”

“Amazing mind opener for those interested in electronics.”

“I liked the way the course was structured to introduce the reader to the main concepts (stability, compensation, differential operation and common mode feedback, noise) of OTAs while illustrating and comparing how those concepts present themselves in each different OTA topology, allowing the reader to formulate an intuition of the trade-offs present in each topology, while reinforcing his generalized understanding of the aforementioned concepts.”

“The training was very wonderful. I learned many amazing topics. Actually, I did not think the IC analog design is that complicated, but it is a very interesting field. I was very happy

with my efforts, and the most wonderful moment was when I saw the specs I was looking for shown in front of my eyes. I think we are very lucky to have this amazing course."

"A wonderful experience! What I liked most about the training is learning how to use Pyxis, which happens to be a wonderful simulation tool."

"I'm very pleased I was a part of this training, each time I learn more and more. The doctor was explaining the topic in different ways, the assistants were helpful, they helped us a lot, and there was a good environment to learn."

"The content of the course was very organized as if you are telling someone a story. Thank you for this amazing work."

"This course helped me to understand the nature of analog designer's work and the obstacles they face."

"I have been a self-learner in electronics for 9 years, and till now I learned not too much compared with what I learned with you during these 5 weeks."

"Labs are the best, even better than Berkeley labs that I had tried myself."

"I am really thankful for your course. Actually, you are my best instructor in analog IC design and your lectures will be my best reference. I didn't have a chance to find an instructor like you in my undergrad or graduate life, so I am really grateful for this opportunity."

"The course was heavy but exciting and challenging. Every day I learned a new set of skills. I am very happy that I have taken this course. The instructor - Dr. Hesham Omran - was beyond helpful, and most importantly, he will always cheer you up."

"The course contents and delivery are excellent and very professional, contents are very sufficient for someone with good basics, in addition to the labs that make the topics more understandable. I highly recommend this course to anyone who is interested about analog/mixed signal design."

"Very great course and very helpful for those who will be work in this field in the future."

"It was an excellent course with a lot of benefits that changed my thinking and understanding towards circuits and analysis... thanks :)"

"This course is a great experience that we will never have alone, and the lecturer is a very great and very experienced person"

"Overall, the training was amazing. It wasn't easy but I enjoyed it. I strongly recommend attending this training for future analog designers."

" الكورس مش بس جزء علمي، لكن جزء اجتماعي كمان. واحد من أفضل الكورسات/التدريبات اللي حضرتها في حياتي وهفضل فاكرها دايما."

"It's definitely a rewarding experience that's worth recommending."