ELEC9701
Mixed signal microelectronics design
Course Outline – Semester 2, 2015

Never Stand Still | Faculty of Engineering | School of Electrical Engineering and Telecommunications

Course Staff

Course Convener: Torsten Lehmann Room 208 t.lehmann@unsw.edu.au

Consultations: You are encouraged to ask questions on the course material in class time, during the consultation time, or via Moodle rather than via email. *All* email enquiries should be made from your student email address with ELEC9701 in the subject line.

Keeping Informed: Announcements may be made during classes, and/or via online learning and teaching platforms – in this course, we will use Moodle https://moodle.telt.unsw.edu.au/login/index.php. Please note that you will be deemed to have received all announcements.

Course Summary

Contact Hours

The course consists of 2.5 hours of lectures and a half-hour discussion class each week. Discussion classes start in week 2.

	Days	Time	Location
Lectures	Wednesdays	6–8.30pm	ElEng-218
Discussion classes	Wednesdays	8.30–9pm	ElEng-218
Consultation	Wednesdays	3–4pm	ElEng-208

Context and Aims

Microelectronics or integrated electronics are the miniaturised electronic circuits that make up Integrated Circuits (ICs) such as microprocessors, Field-Programmable Gate Arrays, Flash-memories, operational amplifier, analogue-to-digital converters and many other functions. Most ICs today are implemented in various flavours of CMOS technology which is the focus of this course. The ability to use large number of components at relative low cost and the ability to match components accurately on-chip makes the design of integrated circuits and systems different from a similar design using discrete components. *Mixed Signal Microelectronics Design* is a broad based, more advanced IC design course, which present the students with analogue and digital circuits and design techniques required to implement mixed-signal integrated circuits with good performance.

Aims: The course aims to enable the student to do analysis and design of integrated circuits of good performance, and to equip the student to do self-guided, continuing learning in the advancing field of microelectronics.

Indicative Lecture Schedule

Period	Summary of Lecture Program	Reading Material
Week 1	Advanced CMOS technologies and components.	Notes.
Week 2	Scaling, Layout matching, process variations.	JB ch. 5, 6, 20, notes.
Week 3	Parasitics, wire models, non-linear capacitances.	JB ch. 3, 4, 5.
Week 4	Advanced MOS models and matching models.	JB ch. 9, 10, notes.
Week 5	Advanced cascodes and HF analysis. **Quiz 1**.	JB ch. 20, 21, 22.
Week 6	Advanced operational amplifier design.	JB ch. 24, 26, 23.
Week 7	Active filters and non-linear circuits.	JB ch. 25, 27, notes.
Week 8	Advanced A/D converter design.	JB ch. 29, notes.
Week 9	Logic effort, sizing, power dissipation. **Quiz 2**.	JB ch. 11, notes.
Break		
Week 10	Advanced logic, special functions, PLLs.	JB ch. 12, 18, 19, notes.
Week 11	Dynamic logic, registers and timing.	JB ch. 13, 14, notes.
Week 12	Packaging, I/O and mixed-signal design.	JB ch. 1, 3, 4, notes.

JB: J. Baker

Indicative Discussion Schedule

Period	Summary of Discussion Program
Week 2	Discussion topic 0: integrated technology/devices.
Week 3	Discussion topic 1: integrated technology/devices.
Week 4	Discussion topic 2: integrated technology/devices.
Week 5	Discussion topic 3: integrated analogue circuits.
Week 6	Discussion topic 4: integrated analogue circuits.
Week 7	Discussion topic 5: integrated analogue circuits.
Week 8	Discussion topic 6: integrated analogue circuits.
Week 9	Discussion topic 7: integrated analogue circuits.
Break	
Week 10	Discussion topic 8: integrated digital circuits.
Week 11	Discussion topic 9: integrated digital circuits.
Week 12	(Discussion topic 10: integrated digital circuits.)
Week 13	**Project report** due.

Assessment

Discussion classes	10 %
Quizzes	10 %
Project design task and report	15 %
Final Examination (3 hours)	65 %

Course Details

Credits

This is a 6 UoC course and the expected workload is 10–12 hours per week throughout the 13 week semester.

Relationship to Other Courses

This is a graduate level course in the School of Electrical Engineering and Telecommunications. It is offered to students following a post-graduate program at the university and is a requirement for students doing research in the area of integrated circuit design.

Pre-requisites and Assumed Knowledge

The course builds on the integrated circuit design foundations given in the undergraduate course ELEC4602, Microelectronics Design and Technology. ELEC4602 is a pre-requisite for this course, but the two courses can be followed concurrently. It is essential that you have good working knowledge of circuit theory, basic analogue and digital electronics, and basic signal analysis as covered in the courses ELEC1112, Electrical Circuits, ELEC2133, Analogue Electronics, ELEC2141, Digital Circuit Design, ELEC2134, Circuits and Signals, and ELEC3106, Electronics which is the pre-requisite course for ELEC4602. It is finally assumed that you are proficient in the use of personal computers and are familiar with SPICE-type circuit simulation.

Learning outcomes

After successful completion of this course, you should be able to:

1. appreciate capabilities and limitations of advanced microelectronic (or IC) technologies,
2. understand and use advanced circuit models of IC components,
3. analyse analogue and digital microelectronic circuits,
4. design analogue, digital and mixed microelectronic circuits,
5. critically read and present papers from technical journals, and
6. keep up-to-date with future technological development in the field.

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in Appendix A. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in Appendix B). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in Appendix C.

Syllabus

Special IC processes, high-voltage, silicon-on-insulator, nano scale CMOS. Scaling, process variation, matching, layout for matching. Parasitics and wire models. Advanced transistor modelling, velocity saturation, sub-threshold. High-frequency analysis. Cascode OTAs, fully-differential circuits, rail-to-rail circuits, power outputs, biasing and references. Trimming. Active filters, switched capacitor circuits, transconductors and Gm-C filters. Non-linear circuits. Schmitt triggers and charge pumps. Sigma-delta converters and automatic calibration. Logic effort. Advanced logic families, rationed logic, special functions, PLLs. Dynamic logic, TSP registers, timing, clock distribution, self-timed systems. Packaging, latch-up, I/O design, ESD, shielding and mixed analogue-digital design. Current research.

Teaching Strategies

Delivery Mode

- Formal face-to-face lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations and individually targeted illustrations to aid your understanding;
- Self-guided tutorials, which allow for exercises in problem solving and allow time for you to resolve in-depth problems for quantitative understanding of the lecture material;
- Discussion classes, which practice critical analysis and detailed discussion of design engineer's primary source of knowledge for keeping abreast a rapidly developing field: research papers.
- A design task, which draws together theoretical and practical design aspects in an open-ended realistic design problem, reinforcing the course material.

Learning in this Course

You are expected to attend all lectures, discussion classes, and quizzes, in order to maximise your learning. You must prepare well for discussion classes and your participation will be assessed. You should read relevant sections of the recommended texts. Lecture notes will not be given: reading and reflecting on the recommended texts and identify critical parts with the aid of the lectures is an essential component of this course. Reading additional texts will further enhance your learning experience. Group learning is also encouraged. UNSW assumes that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Lectures

During the lectures technology capabilities and design issues are discussed and theoretical aspects of IC design and technology are presented. Numerous examples of analogue and digital integrated circuit functions are discussed in order to convey a qualitative understanding of circuit operations. You are encouraged to actively engage in the lectures to facilitate two-way communication and enhance learning. The lectures aim to support you in analysing and designing integrated circuits, and to help you appreciate the capabilities of IC technologies.

Self-guided Tutorials

You should attempt all of the problem sheet questions provided. Group learning is encouraged. Answers to these questions may be discussed during the consultation time.

Discussion classes

Technical papers are the researcher's and practicing design engineer's primary source of knowledge for keeping abreast a rapidly developing field. During the discussion classes, students and lecturer will discuss papers from technical journals; from week 3 onwards, students will take turns to lead these discussions. The discussion classes thus provide you with exercises in critically analysing and reflective learning from technical papers; they also provide you with exercise in oral communication and with advanced, contemporary discipline knowledge. The discussion classes aim to prepare you for future self-guided learning. You are required to participate in the discussion classes.

Design Task

The design task aims to draw together theoretical and practical design aspects in an open-ended realistic design problem. You will design an integrated circuit meeting given specifications, use the CAD tools to verify the circuit operation and write a report in the form of a technical paper documenting your design. The design task provide and test engineering creativity, open-ended problem solving skills, communication skills and general understanding of the course content. You may use the CAD tools in room EEG16/EEG20 for this task.

Assessment

The assessment scheme in this course reflects the intention to assess your learning progress through the semester. Ongoing assessment occurs through the discussion classes, and class-time quizzes.

Discussion Classes Assessment

Participation in the discussion classes is assessed in order to ensure that the students are able to critically read and learn from technical papers, and communicate their findings to the class. Assessment is grade-only marks and are given on basis on activeness of participation and on the ability to learn from the papers and to lead the discussions. A HD mark is given only for exceptional performance and engagement; active participation is required for a PS mark.

Design Task Assessment

The design task is assessed to test your ability to design an integrated circuit and communicate its key features in a professional manner, thus also demonstrating your appreciation of the technology, your ability to use appropriate models and simulations, and your ability to conduct suitable analysis to aid in the design.

You should maintain a lab book and must record suitable screen shots or print-outs as documentation for your work. The design and verification work must be documented in a report which is due Friday the due week listed in the course schedule. The report must take the form of a four-page technical paper (IEEE format). Late submissions carry a 50% penalty for the first week and will not be accepted beyond one week delay. Delays on medical grounds are accepted. Each report must be uploaded as a `.pdf` file (no other format accepted) on the course Moodle site.

Assessment marks (grade only) will be awarded on the basis of your report according to your understanding of the design problem, simulations carried out, the quality and innovativeness of your design, and your ability to concisely explain and characterise your design in your report. A HD mark is given only for exceptional performance; a serious attempt at completing the problem is required for a PS mark.

Quizzes

There are two quizzes held during the lecture time through the semester. These are designed to give early feed-back on your progress through the theoretical components of the course and test your general understanding of the course material. Questions will be drawn from course material covered in the four weeks prior to each quiz. Assessment marks are given according the correct fraction of the answers to the quiz questions.

Final Examination

The exam in this course is a standard closed-book 3 hour written examination. University approved calculators are allowed. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including discussion classes), unless specifically indicated otherwise by the lecturer. Assessment marks will be assigned according to the correctness of the responses.

Relationship of Assessment Methods to Learning Outcomes

	Learning Outcomes					
Assessment	**1**	**2**	**3**	**4**	**5**	**6**
Discussion classes	✓				✓	✓
Design task and report			✓	✓		
Quizzes	✓	✓	✓			
Final examination		✓	✓	✓		✓

Course Resources

Textbooks

Prescribed textbook

- R. J. Baker, *CMOS Circuit Design, Layout, and Simulation*. Wiley Interscience, 2nd/3rd ed., 2005/2010.

Reference books

- T. C. Carusone, D. A. Johns and K. W. Martin, *Analog Integrated Circuit Design*. Wiley and Sons Inc., 2nd ed., 2012.
- T. H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*. Cambridge University Press, 1998.
- N. Weste and D. Harris, *CMOS VLSI Design: a Circuits and Systems Perspective*. Addison-Wesley, 3rd ed., 2005.

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to upload lab reports, host forums and disseminate some course material. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

Course webpage

The course webpage is used to disseminate course material, including the design brief, past assessment and examination papers, and some lecture notes: https://subjects.ee.unsw.edu.au/elec9701.

CAD resources

Students can access the industry standard Cadence design suite for the work in this course. The CAD tools are located in the computer laboratories EEG16/EEG20 and students should have after hours access here. Students must remember to copy their work on to their own storage device before they logout as all data will otherwise be lost. For specific details on how to log on,

see the course web page. Students who have not followed ELEC4602 are encouraged to go through the ELEC4602 laboratory exercises in order to familiarise themselves with the CAD tools.

Other Matters

Academic Honesty and Plagiarism

Plagiarism is the unacknowledged use of other people's work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism, see: https://student.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

Student Responsibilities and Conduct

You are expected to be familiar with and adhere to all UNSW policies (see https://student.unsw.edu.au/guide), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **ten to twelve hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both face-to-face classes and independent, self-directed study. In periods where you need to need to complete assignments or prepare for examinations, the workload may be greater. Over-commitment has been a common source of failure for many students. You should take the required workload into account when planning how to balance study with employment and other activities.

Attendance

Regular and punctual attendance at all classes is expected. UNSW regulations state that if students attend less than 80% of scheduled classes they may be refused final assessment.

General Conduct and Behaviour

Consideration and respect for the needs of your fellow students and teaching staff is an expectation. Conduct which unduly disrupts or interferes with a class is not acceptable and students may be asked to leave the class.

Work Health and Safety

UNSW policy requires each person to work safely and responsibly, in order to avoid personal injury and to protect the safety of others.

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. You should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through myUNSW within 3 working days of the assessment**, not to course or school staff. For more detail, consult: https://student.unsw.edu.au/special-consideration.

Continual Course Improvement

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via

the Course and Teaching Evaluation and Improvement Process. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings. As a result of previous feedback obtained for this course, and in our efforts to provide a rich and meaningful learning experience, we have changed the weighting of in-semester assessments, increased the number of tutorial exercises, and released summary slides.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School and UNSW policies: http://www.engineering.unsw.edu.au/electrical-engineering/policies-and-procedures and https://student.unsw.edu.au/guide.

Appendices

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows:

- Developing scholars who have a deep understanding of their discipline, through discussion classes and design task.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems, through tutorial exercises and design task.
- Developing capable independent and collaborative enquiry, through discussion classes.
- Developing digital and information literacy and lifelong learning skills, through lectures, class preparations and report writing.
- Developing the capability of effective communication, through report writing.
- Developing independent, self-directed professionals who are enterprising, innovative, creative and responsive to change, through the design task.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	Program Intended Learning Outcomes	
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	✓
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	✓
	PE1.3 In-depth understanding of specialist bodies of knowledge	✓
	PE1.4 Discernment of knowledge development and research directions	✓
	PE1.5 Knowledge of engineering design practice	✓
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	✓
	PE2.2 Fluent application of engineering techniques, tools and resources	✓
	PE2.3 Application of systematic engineering synthesis and design processes	✓
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	
	PE3.2 Effective oral and written communication (professional and lay domains)	✓
	PE3.3 Creative, innovative and pro-active demeanour	✓
	PE3.4 Professional use and management of information	✓
	PE3.5 Orderly management of self, and professional conduct	✓
	PE3.6 Effective team membership and team leadership	