School of Electrical Engineering and Telecommunications

Term 1, 2019
Course Outline

ELEC9703
Microsystems Design &Technology

COURSE STAFF

Course Conveners: Dr. Aron Michael (Rm 316) & Prof. Chee Yee KWOK (Rm 344)

a.michael@unsw.edu.au cy.kwok@unsw.edu.au

Consultations: You are encouraged to ask questions on the course material, during and after the lecture class times in the first instance, rather than via email. Lecturer consultation times will be advised during lectures. You are welcome to email the lecturer to arrange for a consultation time. ALL email enquiries should be made from your student email address with ELEC9703 in the subject line, otherwise they will not be answered.

Keeping Informed: Announcements may be made during classes, via email (to your student email address) 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 this information, so you should take careful note of all announcements. The Moodle name of this course is **ELEC9703 Microsystems Design and Technology T1/2019.**

COURSE SUMMARY

Microsystems technology is ***multidisciplinary*** in nature. It is also known as MEMS (**M**icro-**E**lectro-**M**echanical **S**ystems) technology. The most important disciplines that intersect with Microsystems work are electrical engineering, mechanical engineering, microelectronic engineering, physics, material science, chemistry, fluidic engineering, photonics, biomedical engineering, biosciences etc. MEMS is truly an ***enabling technology*** which has penetrated into and begun to change the way major discipline do things, including biotechnology, storage technology, instrumentation, telecommunications, optical communications, Integrated Circuits and MEMS device packaging, medical technology etc. MEMS research, engineering development and modern manufacturing processes require close integration and collaborative interaction of experts from many disciplines. On the other hand MEMS researchers and engineers must be willing to cross interdisciplinary boundaries and acquire knowledge outside their discipline of expertise. Examples of MEMS devices produced in large volumes include, pressure sensors, flow sensors, inertial measurement units(IMU) like accelerometers and gyroscopes, micro-valves and micro-pumps, projection display chips, biosensors, inkjet nozzle arrays, optical cross-switches, RF switches, Lab on a Chip, etc., etc.

In short, this course will cover a wide range of topics related to MEMS fabrication technology and expand on to some of the design issues, bearing in mind the technology constraints. Can it manufactured?! It will include examples of the design and fabrication of physical sensors like gyroscopes, accelerometers, etc. Furthermore, a course is not complete if we do not know what the current market drivers are for MEMS products and where the future holds for this exciting and fast expanding technology. Many people do not realise that the numerous savvy features we have in our mobile smart devices stem from advances in MEMS technology.

The subject will enable students to have a broad grasp of the multi-disciplinary nature of MEMS technology, bringing together the know-how of physicist, chemist, electrical and mechanical engineers, and mathematicians. It will provide the fundamental knowledge for students, who want to enter the MEMS industry. It is an exciting field of research and we should count ourselves fortunate to be witnessing and participating in this era of unparalleled technology advancement.

Contact Hours:

This postgraduate course consists of 3 hours of lectures in the evenings. Problem discussions are included in the lectures and will not be treated as separate tutorials. The lectures will be recorded and students can refer to them at a later date. Note that this is not a replacement for lecture attendance. Furthermore, some of the topics will be covered by **pre-recorded lectures**. Students will be notified as to when these recorded lectures will be available as the course progresses. Please note that **materials covered in the pre-recorded lectures are also examinable.**

Lectures	Day	Time	Location
	Wednesday	6-9pm	BUS220

Context:

The entire field of research in microsensors and microactuators has evolved at an exceedingly rapid pace over the past 35 years. It is often referred to as MEMS (MicroElectroMechanical Systems) or Microsystems Technology. Signals from the physical world around us are always in analog form. Yet, much of the signal processing is done in digital form by microelectronic circuits. Microsensors and microactuators are the interfaces between the digital electronic domain and the physical world. Sensors and actuators in various forms have been around for centuries but significant miniaturisation was not possible until the last few decades due to the significant technological advances in microfabrication techniques. In many cases, these new devices bring along new advantages over the traditional components like several orders of magnitude in size reduction, new functionality, and possibly integration of on-chip signal processing circuit (smart sensors/actuators). Many of the micro-fabrication techniques originate from the wealth of processes developed for the fabrication of integrated circuits. Yet, the MEMS business cannot be simply compared to the IC(Integrated Circuits) business. ICs deal with electrical signals whereas MEMS devices are interfaces to the physical world, to and from the electrical domain. As such, one would expect a more diverse, a more complicated overall environment, interacting effectively and accurately between the electronic domain and the outside world. The natural outcome of this is the vast and diverse range of MEMS devices. In fact, if one word were to be used to characterize the field of MEMS or Microsystems, it would be its ***multidisciplinary*** nature. The most important disciplines needed for Microsystems work are electrical engineering, mechanical engineering, microelectronic engineering, physics, material science, chemistry, fluidic engineering, photonics, biomedical engineering, biosciences etc. MEMS is truly an ***enabling technology*** which has penetrated into and begun to change the way major discipline do things, including biotechnology, storage technology, instrumentation, telecommunications, optical communications, MEMS device packaging, etc. etc. MEMS research, engineering development and manufacture must require close integration and collaborative interaction of experts from many disciplines. On the other hand MEMS researchers and engineers must be willing to cross interdisciplinary boundaries and acquire knowledge outside their discipline of expertise. Examples of MEMS devices produced on large volumes include, pressure sensors, accelerometers, micro-valves, micro-pumps, projection display chips, biosensors, inkjet nozzle arrays, optical cross-switches, RF switches, Lab-on-chip etc. .

Aims:

The course aims to expose students to the MEMS fabrication technology and the may design approaches, and enable them to appreciate the many advances in the technology that has become the 'enabling technology' for many other disciplines. It is also the aim of the course to highlight the multidisciplinary nature of the course and its impact on design issues.

Indicative Lecture Schedule

Period	Lecture Topics	Due dates
Week 1 (20/2)	Introduction to Microsystems: an overview and technology trends. Lithography.	
Week 2 (27/2)	Thin Film Processes	
Week 3 (6/3)	Bulk Silicon Micromachining	
Week 4 (13/3)	Surface micromachining	
Week 5 (20/3)	High Aspect Ratio Micromachining (HARM)	
Pre-recorded Lecture	Bonding Processes	
Week 6 (27/3)	Mechanics: Properties of materials, structures, energy methods	Assignment 1 due
Pre-recorded Lecture	Introduction to ANSYS Simulation: Electro-thermal, Piezoelectric and Electrostatic	
Week 7 (3/4)	Lumped modelling with circuit elements and system dynamics	Mid-session exam (1.0 hr) at 5pm. Location to be advised
Week 8 (10/4)	Actuation mechanisms: Electrostatic, Electromagnetic, Electrothermal, and Piezo-electric. Case studies.	
Week 9 (17/4)	Inertial sensors: Accelerometer, Gyroscope, pressure transducers	
Week 10 (24/4)	Optical MEMS, Microfluidic basics and Bio-MEMS	Assignment 2 due

Assessment

Assignment 1	**12.5%**
Assignment 2	**12.5%**
Mid-Semester Exam (1.0 hours)	**20%**
Final Exam (2 hours) – Open Notes	**55%**

Course Details

Credits

This is a 6 UoC course and the expected workload is 15 hours per week throughout the 10 weeks session.

Relationship to Other Courses

This is a postgraduate course offered to students in the Master of Engineering Science (8338) and Master of Engineering Coursework (8621) in the Faculty of Engineering at the University of New South Wales. ELEC 9704 provides some of the ground work required for this course.

Pre-requisites and Assumed Knowledge

There is no specific pre-requisite for the course. However, it will be beneficial for students who are familiar with semiconductor technology which is covered in ELEC9704.

It is further assumed that the students are familiar with some basic chemistry, physics, mechanics, electrical engineering etc. The course is very multidisciplinary in nature and students are challenged to do this course with <u>an open mind</u> to learn, be creative and innovate.

Learning outcomes

After the successful completion of the course, the student will be able to:

1. Understand a range of technologies used for micro-fabrication.
2. Understand the principle of operations of micro-sensors and micro-actuators.
3. Analyse and design of micro-sensors and micro-actuators.
4. Understand the design flow procedure for MEMS device.
5. Simulate micro-actuators using ANSYS simulation software.
6. Design micro-fabrication process flow to make MEMS devices.
7. Appreciate the multi-disciplinary nature of micro-systems.

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

Introduction to Microsystems: an overview and trends ; Lithography and Thin Film Processes ; Surface micromachining **;** Bonding Processes; High Aspect Ratio Micromachining (HARM); Mechanics: Properties of materials, structures, energy methods ; Actuation mechanisms: Electrostatic, Electromagnetic, Electrothermal, and Piezo-electric ; Lumped modelling with circuit elements and system dynamics ; Introduction to ANSYS Simulation: Electro-thermal, Piezoelectric and Electrostatic ; Optical MEMS, Microfluidic basics and Bio-MEMS.

Teaching Strategies

Delivery Mode

The teaching in this course aims at establishing a good fundamental understanding of the areas covered using:

- Formal face-to-face lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
- There are no separate tutorials but done lectures from time to time. Some self-paced exercises will be given out in class during the course.
- Where possible, lectures will be videoed and uploaded to the school website for students to clarify specific aspects of the lecture. It is not a substitute for missed lectures.

Learning in this course

You are expected to attend <u>all</u> lectures, and attempt assignments in order to maximise learning. In addition to the lecture notes/video, you should read relevant sections of the recommended reference text. 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.

Tutorial classes

There are no separate tutorial classes.

Laboratory program

There are no laboratory programs. However, a short lab tour of Australian National Fabrication Facility (NSW node) is arranged towards the later part of the course (outside the 6-9pm lecture times).

Assessment

Assignment 1	12.5%
Assignment 2	12.5%
Mid-session exam	20%
Final Exam (2 hours closed book)	55%

1. ***<u>Assignments:</u>*** There are two compulsory written **assignments** for this course, which will be released on the course Moodle in Weeks 4 and 8 respectively. The assignments will each be worth 12.5% of the overall mark in total for this course. It is expected that the students complete assignments on their own. **Plagiarism will not be tolerated**. Assignment submissions dates are set on Mondays in week 6 and 10 for each assignment respectively.

2. ***<u>Mid-session exam:</u>*** A mid-session exam will be conducted on **Wednesday of week 7 starting at 5pm**. Location for the exam will be announced during the course. Note: It will be conducted outside of the normal class lecture times of 6-9pm. It will be a **closed book** exam. Students are strongly advised to take the mid-session exam seriously as it contributes **20%** to the overall marks of the course.

3. ***<u>Final exam</u>***: It will be an **OPEN NOTES of** 2 hour final exam.

The assessment scheme in this course reflects the intention to assess your learning progress through the term.

Mid-session and Final Exams

The **mid-session exam in this course are closed-book** written examination but the **final exam will be OPEN NOTES** written exam. 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, unless specifically indicated otherwise by the lecturer. Further details will be given during the lectures. Marks will be assigned according to the correctness of the answers and not the volume of written material in the answer scripts.

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes							
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
Assignment1	x	x	x	x		x		
Assignment 2	x	x	x	x	x	x	x	
Mid-session exam	x	x	x	x			x	
Final exam	x	x	x	x			x	

COURSE RESOURCES

Textbooks

The no textbook set for this course but a good reference book to buy is by JD Plummer or S Sze. The following are the recommended reference books.

In the view of the wide range of disciplines in this course, there is no single textbook that appropriately covers all the course material. Hence, it does not have prescribed textbook. However, the following reference books and articles are recommended:

1. MJ Madou, “Fundamentals of Microfabrication”, CRC Press (good text to buy)
2. GTA Kovacs, “Micromachined Transducers sourcebook,” McGraw Hill, 1988.
3. S D Senturia, “Microsystems Design”, KAP, 2001.
4. L. Ristic, “Sensor Tchnonology and Devices”, AH, 1994.
5. P. Rai-Choudhury, “Microlithography, Micromachining, and Microfabrication”, Vo..2, SPIE Press, 1997.
6. M Elwenspoek and HV Jansen, “Silicon Micromachining,” CUP 1998.
7. SA Campbell, “The Science and Engineering of Microelectronics Fabrication”
8. S. SZE, “VLSI Technology”, McGrawHill
9. Gere & Timoshenko, “Mechanics of Materials”
10. Roark, “Roark’s Formula for Stress and Strain,” McGrawHill, 6^{th} Ed, 1989.
11. M Lambrechts &W Sansen, “Biosensor- Micorelectromechanical devices”, IOP, 1992.
12. JW Gardner, “Microsensors”, Wiley, 1994.
13. IEEE Journal of Micro-Electro-Mechanical Systems
14. Sensors and Actuators A: Physical
15. Journal of Micromechanics and Microengineering
16. Proceedings from Transducers conferences
17. Proceedings from IEEE MEMS conferences

18. Proceedings from EUROSENSOR conferences
19. Procedia Engineering

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

Mailing list

Announcements concerning course information will be given in the lectures and/or on Moodle and/or via email (which will be sent to your student email address).

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

Students 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. As of Term 1 2019, assessment of applications for Special Consideration (https://student.unsw.edu.au/special-consideration) will be managed centrally and the University has introduced a "fit to sit/submit" rule. You will no longer be required to take your original documentation to The Nucleus for verification. Instead, UNSW will conduct source checks on documentation for verification purposes. You can apply for special consideration when illness or other circumstances beyond your control interfere with an assessment performance. If you need to submit an application for special consideration for an exam or assessment, you must submit the application **prior to the start** of the exam or before the assessment is submitted, except where illness or misadventure prevent you from doing so. If you sit an exam or submit an assignment, you are declaring yourself well enough to do so.

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 online student survey myExperience. You can also provide feedback to ELSOC who will raise your concerns at the 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 continued to evaluate and modify our delivery and assessment methods.

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:

https://student.unsw.edu.au/guide

https://www.engineering.unsw.edu.au/electrical-engineering/resources

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 lectures and solution of analytical problems in tutorials and assessed by assignments and written examinations.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Developing capable independent and collaborative enquiry, through a series of assignments spanning the duration of the course.
- Developing digital and information literacy and lifelong learning skills through assignment work.
- Developing ethical practitioners who are collaborative and effective team workers, through group activities, seminars and tutorials.
- Developing independent, self-directed professionals who are enterprising, innovative, creative and responsive to change, through challenging design and project tasks.

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	