UNSW SYDNEY Australia's Global University

School of Electrical Engineering and Telecommunications

Term 1, 2020

Course Outline

ELEC4621

Advanced Digital Signal Processing

COURSE STAFF

Course Convener:	A/Prof. Elias Aboutanios	Room 445	elias@unsw.edu.au
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Laboratory Contact:	TBA		

Consultations: You are encouraged to ask questions on the course material as well as any other related matter through the Moodle forum. This should be the primary avenue of consultation for the benefit of the entire class. You may also ask questions after the lecture class times if time permits. The use of email is highly discouraged and should be only a last resort (or if a matter needs private contact with the lecturer). When emailing the lecturer, ALL email enquiries should be made from your student email address with ELEC4621 in the subject line, otherwise they will not be answered. When necessary, lecturer consultation times will be set and posted on Moodle.

Keeping Informed: Announcements may be made primarily via Moodle, so it is imperative for you to keep checking the Moodle page of the course https://moodle.telt.unsw.edu.au/login/index.php. Whenever possible, they will also be announced during classes and/or via email (to your student email address). Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

COURSE SUMMARY

Contact Hours

The course comprises lectures, tutorials, and laboratory sessions each week as described in the table below. Note that, due to the move to the 10 week format, this arrangement may change if any issues are identified.

	Days	Time	Location	Weeks
Lectures	Monday	10am - 12pm	Ainsworth 102	1-8, 10-11
	Wednesday	1 - 3pm	Red Centre M032	1-6
	Wednesday	1 - 2pm	Red Centre M032	7-10
Tutorials	Monday	1 - 2pm	Bus 205	1-8,10-11
	Monday	2 - 3pm	Bus 205	1-8,10-11
Labs	Tuesday	2 - 5pm	ElecEng 108	1-10
	Wednesday	3 - 6pm	ElecEng 108	1-10
	Thursday	9am - 12pm	ElecEng 108	1-10
	Thursday	12 - 3pm	ElecEng 108	1-10

Context and Aims

This subject builds upon the material introduced in Elec3104, focusing exclusively on digital signal processing techniques. Most signals exist in the real world in analog form. However, the large proportion signal processing is nowadays done on digital processors (including your smartphone). This naturally requires a conversion of the real-world signals to digital form and then conversion back to the analog form following the processing. Digital signal processing offers a number of advantages over analog signal processing. Firstly, digital processors can be easily reconfigured by changing the code (algorithm) and therefore hardware changes can often be avoided if there is a change in the scenario. This flexibility can reduce cost. Secondly, once a signal is transformed to a series of numbers, a myriad of mathematical tools can then be applied that would otherwise be difficult or even impossible on an analog processor. In fact, we may think of signals as mathematical objects that have certain properties and to which a vast array of mathematical tools can be used.

In this subject, we aim to give you a good grasp of important concepts that allow this process to take place. These include the conversion from analog to digital and vice versa, digital filtering, transforms, noise and its implications, estimation and prediction. The subject is effectively divided into two main parts: deterministic signal processing and statistical signal processing.

Below is an indicative topics list:

- Sampling, aliasing and the relationship between discrete and continuous signals
- Review of Fourier transforms, the Z-transform, FIR and IIR filters, and oscillators
- Filter implementation techniques, structures and numerical round-off effects Filter design techniques
- Auto-correlation, cross-correlation, and power spectrum estimation techniques
- Detection
- Estimation
- Linear prediction
- Wiener filters, LMS adaptive filters, and applications.
- Multi-rate signal processing and subband transforms.
- Time-frequency analysis, the short time Fourier transform, and wavelet transforms.

Note that we may not cover all of these topics, but we will endeavour to get through as many of them as possible during the trimester.

Indicative Lecture Schedule

This schedule is indicative and subject to change in order to ensure the optimal learning experience is provided. Changes will be announced on Moodle.

Period	**Summary of Lecture Program**
Week 1	Introduction, linear spaces, signal representation
Week 2	Transforms, linear time-invariant operations, filters
Week 3	filter structures, filter design
Week 4	Filter implementation, numerical roundoff errors, quantization effects
Week 5	introduction to multi-rate signal processing, sub-band transforms
Week 6	Statistics, information, power spectrum estimation, Quiz 1
Week 7	Linear prediction, Weiner filtering
Week 8	Signal Detection, hypothesis tests, likelihood ratio tests
Week 9	Parameter Estimation
Week 10	time-frequency analysis, space-time processing, the Short-time Fourier Transform

Indicative Laboratory Schedule

Period	**Summary of Laboratory Program**
Week 2	Lab 1
Week 3	Lab 2
Week 4	Lab 3
Week 5	Lab 4
Week 6	No lab
Week 7	Lab 5
Week 8	Lab Project
Week 9	Lab Project
Week 10	Lab Project

Assessment

Laboratory Assessment	30%
Quiz	20%
Final Exam (2 hours)	50 %

COURSE DETAILS

Credits

This is a 6 UoC course and the expected workload is 15 hours per week throughout the 10 week semester. The University defines a UoC as requiring 25 hours of total learning effort per semester (spread over lectures, tutorials, labs, and the student's own study time.) Therefore, it is expected that 150 hours will be allocated to this course. This covers the contact hours, including lectures, tutorials and labs, as well as the self-study time.

Relationship to Other Courses

This is a 4th year professional elective course in the School of Electrical Engineering and Telecommunications.

Pre-requisites and Assumed Knowledge

The pre-requisite for this course is ELEC3104, Digital Signal Processing. It is also essential that you are familiar with elementary signal processing concepts and linear algebra, as well as various mathematical foundations such as complex analysis, functional analysis, and numerical methods before this course is attempted. It is further assumed that students have a working knowledge of Matlab, which is used in the laboratory projects.

Following Courses

The course is not a pre-requisite for any other courses offered by the School of EE&T. However, students undertaking postgraduate studies involving signal processing should find that this course provides an excellent preparation for such further study. As an undergraduate professional elective, this course provides a solid foundation for a surprisingly wide range of professional engineering design and development activities.

Learning outcomes

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

1. Have a more thorough understanding of the relationship between time and frequency domain interpretations and implementations of signal processing algorithms;
2. Understand and be able to implement adaptive signal processing algorithms based on second order statistics;
3. Understand fundamental statistical signal processing concepts of signal detection and parameter estimation; and
4. Be familiar with some of the most important advanced signal processing techniques, including multi-rate processing and time-frequency analysis techniques.

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

The course is essential comprised of two halves: deterministic signal processing concepts, such as those based on linear time-invariant systems (i.e. filters), and statistical signal processing concepts, such as signal detection and parameter estimation. The syllabus comprises:

1. FIR filters; all-pole IIR lattice filters and their implementation.
2. Fixed-point or finite word length implementations and effects.
3. Random processes; auto-correlation; cross-correlation; and power spectrum estimation.
4. Estimation and detection.
5. Adaptive filters; wiener filters; adaptive noise cancellation.
6. Linear prediction and applications of linear prediction.
7. Multi-rate signal processing systems; quadrature mirror filter banks; multilevel filter banks.
8. Time frequency analysis; short-time Fourier transform; and wavelet transform.

TEACHING STRATEGIES

Delivery Mode

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

1. 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;
2. Tutorials, which allow for exercises in problem solving and allow time for you to resolve problems in understanding of lecture material, while also providing opportunities for you to stretch your understanding to a variety of application domains;
3. Laboratory sessions, which support the formal lecture material and allow you to develop confidence in your ability to convert the formal material into solutions to important practical problems. This semester I am introducing some innovations into the course delivery.

The teaching philosophy is heavily based on the interaction between the lecturer and students. The lecturer's main task is to impart the necessary insights and understanding to the students rather than simply dump mathematical equations on the board or practice sovling problems. In fact, the practice of solving problems rests almost entirely with the students. Students are expected to seek help and ask questions to rectify any misunderstanding they may have or further deepen their knowledge. The course organisation provides many channels and ample opportunity for students to seek clarifications and support.

Learning in this Course

You are expected to attend **all** lectures, tutorials, labs, and mid-semester exams in order to maximise learning. You must prepare well for your laboratory classes and your lab work will be assessed. In addition to the lecture notes/video, you should read relevant sections of the recommended 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

You should attempt all of your problem sheet questions in advance of attending the tutorial classes. The importance of adequate preparation prior to each tutorial cannot be overemphasized, as the effectiveness and usefulness of the tutorial depends to a large extent on this preparation. Group learning is encouraged. Answers for these questions will be discussed during the tutorial class and the tutor will cover the more complex questions in the tutorial class.

Note: while official solutions to problem sets may be made available, reading solutions without first devoting substantial thought to the problems (including revision of lecture notes) is entirely counter-productive and can deprive you of the opportunity to truly come to grips with weaknesses in your understanding. A superior method of study is to discuss challenging questions with your peers, rather than reading solutions.

Laboratory Program

The laboratory schedule is deliberately designed to provide practical, hands-on exposure to the concepts conveyed in lectures soon after they are covered in class. You will find that the assessed laboratories require careful preparation, which is best done by reviewing lecture materials to the point where you understand them thoroughly. You will find that the work put into laboratories more than pays for itself, because preparing for the laboratories is one of the most effective study techniques for the course as a whole.

The laboratories are assessable and they count 30% towards the course assessment. There fibe regular labs and one lab project.

Laboratory Exemption

There is no laboratory exemption for this course. Regardless of whether equivalent labs have been completed in previous courses, all students enrolled in this course must take the labs. If, for medical reasons, (note that a valid medical certificate must be provided) you are unable to attend a lab, you will need to apply for a catch-up lab during another lab time, as agreed by the laboratory coordinator.

ASSESSMENT

The assessment scheme in this course reflects the learning objectives. Assessment in laboratories is intended to encourage you to get the most from these learning experiences. Mid-session tests encourage you to keep on top of the material and to allow both you and your lecturer to discover weaknesses in understanding early. Assessment in the final exam is very important to overall learning in the course; preparation for the final exam provides the best opportunity to appreciate the course as a whole and cement your understanding of its heavily interlinked concepts.

The assessment scheme in this course reflects the intention to assess your learning progress through the semester. Ongoing assessment occurs through the lab checkpoints (see lab manual), lab exams and the mid-semester exam.

Laboratory Assessment

Laboratories are entirely about learning and understanding what you have learned. The laboratory assessment is designed to check your knowledge and understanding as you progress through the course.

Laboratories 1 to 5 are assessed within the lab itself and will be given a grade of satisfactory/unsatisfactory. They contribute 10% toward the final assessment. Completing these labs is required for the final lab project and for passing the course. Only a few minutes of assessment time are reserved for each of you for these labs. The lab project, which is due in Week 10 will result in the submission of a lab report each. Each report is marked and contributes 20% towards the course assessment.

It important, however, to see that the labs are worth much more than the marks as they permit you to apply your knowledge in the confidence that it can build and the understanding it can impart.

The laboratories in this course are design exercises that will typically require you to revise your lecture notes to deepen your understanding of the topic that is covered by the laboratory. This is intended and it is expected that you can demonstrate familiarity with all the relevant lecture material while being assessed. It is, nonetheless, noted that you may have gaps in your knowledge and therefore need help. In this respect, the laboratory demonstrators are highly knowledgeable and helpful. They can assist you to resolve weaknesses in your understanding, but you must raise any concerns that need their assistance near to the beginning of the scheduled laboratory period. Most of the final hour of the lab session will be spent assessing your work. You should follow all instructions given by the laboratory demonstrators to facilitate efficient assessment of your work. Where analytical work is involved, you should have that work available for the laboratory demonstrators to inspect, in a separate neatly presented laboratory book.

Note also that the labs are meant to stimulate discussions. As you attempt the exercises prior to the lab in your own time, you will have the opportunity to discuss the labs in the forums that are provided on Moodle. The questions you ask can be answered by your peers, or by the course teaching staff.

Mid-Semester Exam

The mid-session examination tests your general understanding of the course material, and is designed to give you feedback on your progress through the analytical components of the course. Questions may be drawn from any material already covered in the course schedule. It may contain questions requiring some (not extensive) knowledge of laboratory material, and will definitely contain numerical and analytical questions. Marks will be assigned according to the correctness of the responses.

Final Exam

The exam in this course is a standard closed-book 2 hour written examination, comprising five compulsory questions. 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 laboratory), unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses. Please note that you must pass the final exam in order to pass the course.

Relationship of Assessment Methods to Learning Outcomes

	Learning Outcomes						
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Laboratory practical assessments	✓		✓				
Lab exam				✓			
Mid-semester exam		✓					✓
Assignment						✓	
Final exam					✓		

COURSE RESOURCES

Textbooks

Prescribed textbook

There is no prescribed textbook for this course. Notes and relevant documents as well as recorded videos will be provided to you as appropriate.

Reference books

- Proakis & Manolakis, Digital Signal Processing: Principles, Algorithms and Applications, Prentice Hall.
- Simon Haykin, Modern Filters, Macmillan Publishing Company.

In addition to these two books, other reference books will be posted on Moodle.

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).

OTHER MATTERS

Dates to note

Important dates are available at: https://student.unsw.edu.au/dates

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 **15 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 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 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://www.engineering.unsw.edu.au/electrical-engineering/resources
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 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 tutorials 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.
- Developing citizens who can apply their discipline in other contexts, are culturally aware and environmentally responsible, through interdisciplinary tasks, seminars and group activities.

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	✓