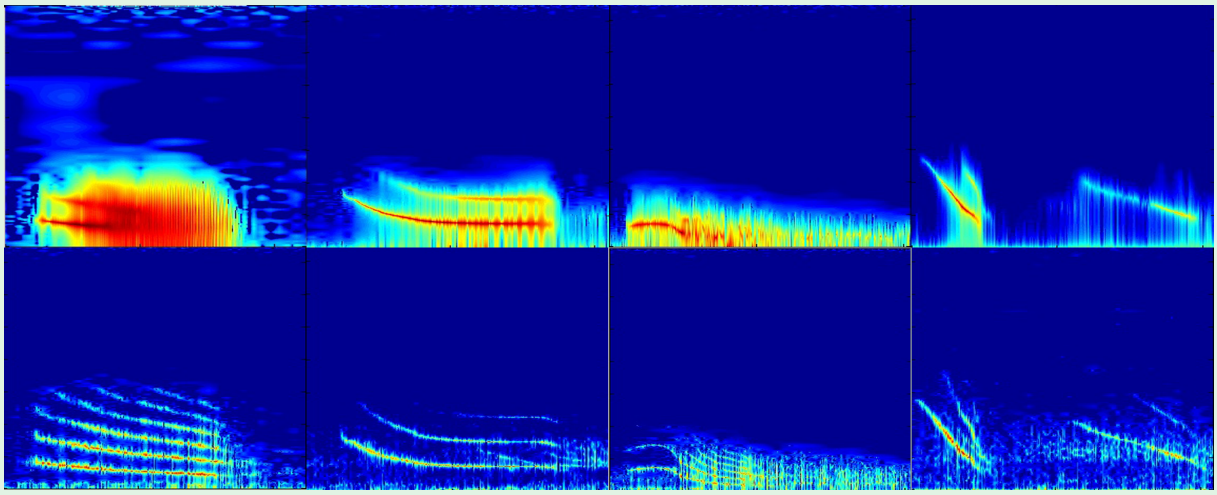
ELEC4621

Advanced Digital Signal Processing

Term 1, 2022



Course Overview

Staff Contact Details

Convenors

Name	Email	Availability	Location	Phone
Elias Aboutanios	elias@unsw.edu.au		EEB 445	430023047

Demonstrators

Name	Email	Availability	Location	Phone
Xinyue Li	x.li@unsw.edu.au			
Mostafa Shahin	m.shahin@unsw.edu.au			
Austin Davis	austin.davis@student.unsw.edu.au			

School Contact Information

Consultations: Lecturer consultation times will be advised during the first lecture. You are welcome to email the tutor or laboratory demonstrator, who can answer your questions on this course and can also provide you with consultation times. ALL email enquiries should be made from your student email address with ELEC/TELExxxx 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.

Student Support Enquiries

For enrolment and progression enquiries please contact Student Services

Web

Electrical Engineering Homepage

Engineering Student Support Services

Engineering Industrial Training

UNSW Study Abroad and Exchange (for inbound students)

UNSW Future Students

Phone

(+61 2) 9385 8500 – Nucleus Student Hub

(+61 2) 9385 7661 – Engineering Industrial Training

(+61 2) 9385 3179 – UNSW Study Abroad and UNSW Exchange (for inbound students)

Email

Engineering Student Support Services – current student enquiries

- e.g. enrolment, progression, clash requests, course issues or program-related queries

Engineering Industrial Training – Industrial training questions

UNSW Study Abroad – study abroad student enquiries (for inbound students)

UNSW Exchange – student exchange enquiries (for inbound students)

UNSW Future Students – potential student enquiries

- e.g. admissions, fees, programs, credit transfer

Course Details

Units of Credit 6

Summary of the Course

This subject builds upon the material introduced in the third year Digital Signal Processing course (Elec3104), focusing exclusively on digital signal processing techniques. Most signal processing is nowadays done on digital processors (including your smartphone). Although some real-world signals are discrete, most signals are in analog form which naturally requires a conversion of these signals to digital form and possibly (though not necessarily always) 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.

This course aims to deepen the understanding gained in the third year course and to extend it by introducing new topics. The subject is divided into

Course Aims

In this subject, we aim to give you a solid foundation in the important concepts that allow this process to take place. These include the conversion from analog to digital and vice versa, signal representation and interpretation, digital filtering, transforms, noise and its implications, detection, 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.

Course Learning Outcomes

After successfully completing this course, you should be able to:

Learning Outcome	EA Stage 1 Competencies
1. Explain the relationship between time and frequency domain interpretations and implementations of signal processing algorithms	PE1.1, PE1.2, PE1.3, PE1.4, PE2.1, PE2.2
2. Explain and implement adaptive signal processing algorithms based on second-order statistics	PE1.1, PE1.2, PE1.3, PE1.4, PE2.1, PE2.2
3. Describe fundamental statistical signal processing concepts of signal detection and parameter estimation	PE1.1, PE1.2, PE1.3, PE1.4, PE2.1, PE2.2
4. Identify some of the most important advanced signal processing techniques, including multirate processing and time-frequency analysis techniques	PE1.1, PE1.2, PE1.3, PE1.4, PE2.1, PE2.2

Teaching Strategies

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

1. **Formal online lectures** that provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
2. **Tutorials** that 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** that 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.

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 deliver these concepts in a dry manner. So the lecturer is not there only to give you the mathematical equations on the board or for practice problem-solving. 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.

In addition to the above components, this course contains a number of other (innovative) elements that have been added for your benefit. These are:

1. **Self-benchmarking exercise:** This exercise requires you to rate your own knowledge of a list of fundamental concepts that you will encounter in this course. You will undertake this exercise both at the start and end of term. At the start of term the test effectively allows you to benchmark your prior knowledge, while at the end of term, it allows you to rate your learning and how far you have advanced during the term. This test is useful for you to make the most out of the course and to reflect on your knowledge both at the start and end of the course.
2. **Benchmarking test:** This is a non-assessable multiple choice quiz that you will take at the start of term. Again, this quiz allows you to test your prior knowledge and together with the self-benchmarking exercise, they give you a very useful benchmark of your knowledge at the start of

the course.

3. **Challenge problems:** These problems will be posted at various times during the term for you to attempt. These problems are chosen to enable you to exercise and validate the knowledge you have gained and to extend it by gaining new insights. Unlike tutorial problems, the challenge problems are not purely aimed at giving practice in the theory you have leraned, but they are inteded to be challenging and fun as well providing deeper insight into the concepts. 4. Videos and other resources: At various points, when seen to be useful or necessary, explanatory videos will be recorded and posted for your benefit on Moodle. Alternatively, other resources, such as documents or links to websites or videos on the internet, will be posted on Moodle.

Additional Course Information

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
his is a 4 th 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.

Assessment

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Lab Tasks and Project	30%	Not Applicable	1, 2, 3, 4
2. Quiz	20%	Not Applicable	1, 2, 4
3. Final Examination	50%	Not Applicable	1, 2, 3, 4

Assessment 1: Lab Tasks and Project

Laboratories are entirely about applying and understanding what you have learned and the laboratory assessment is designed to verify 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/marginal/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.

Hurdle requirement

All laboratory tasks must be completed to pass the course.

Additional details

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.

Assessment 2: Quiz

Assessment length: 50 minutes

The quiz will be held in the middle of the trimester and is intended to give you an opportunity to assess your command of the material up to that point. It serves the very important purpose of allowing you to

identify weaknesses and to rectify them.

Assessment criteria

The quiz will be marked based on your understanding. Giving the right answer will not necessarily guarantee you full marks. On the other hand, by showing your working and demonstrating a proper understanding you can still obtain some marks even if your final answer is incorrect.

Assessment 3: Final Examination

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.

Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

Course Schedule

The indicative schedule is given in the table below. The schedule has some degree of flexibility that will be exercised to maximise your learning.

View class timetable

Timetable

Date	Type	Content
Week 1: 14 February - 18 February	Lecture	**Lecture 1:** Introduction; Linear Spaces; Sampling **Lecture 2:** Signal Representation; Transforms
	Tutorial	Tutorial 1
	Laboratory	Introductory Lab
Week 2: 21 February - 25 February	Lecture	**Lecture 3:** Linear Time-Invariant (LTI) Operations; Filter Structures **Lecture 4:** Filter Design
	Tutorial	Tutorial 2
	Laboratory	Lab Task 1
Week 3: 28 February - 4 March	Lecture	**Lecture 5:** Filter Implementation **Lecture 6:** Numerical Round-off Errors; Quantization Effects
	Tutorial	Tutorial 3
	Laboratory	Lab Task 2
Week 4: 7 March - 11 March	Lecture	**Lecture 7:** Introduction to Multi-rate Signal Processing **Lecture 8:** Sub-band Transforms
	Tutorial	Tutorial 4
	Laboratory	Lab Task 3
Week 5: 14 March - 18 March	Lecture	**Lecture 9:** Statistics; Information Theory Perspective

		Lecture 10: Power Spectrum Estimation
	Tutorial	Tutorial 5
	Laboratory	Lab Task 4
Week 6: 21 March - 25 March	Lecture	Flexibility Week
Week 7: 28 March - 1 April	Lecture	**Lecture 11:** Linear Prediction, **Lecture 12:** Quiz **Lecture 13:** tWeiner Filtering
	Tutorial	Tutorial 6
	Laboratory	Lab Task 5
Week 8: 4 April - 8 April	Lecture	**Lecture 14:** Signal Detection; Hypothesis Testing **Lecture 15:** Likelihood Ratio Tests **Lecture 16:** Parameter Estimation
	Tutorial	Tutorial 7
	Project	Lab Project
Week 9: 11 April - 15 April	Lecture	**Lecture 17:** Time-Frequency Analysis **Lecture 18:** The STFT **Lecture 19:** Data-Adaptive Transforms (the MVE)
	Tutorial	Tutorial 8
	Project	Lab Project
Week 10: 18 April - 22 April	Lecture	**Lecture 20:** Space-Time Adaptive Processing **Lecture 21:** Flexible Session **Lecture 22:** Flexible Session
	Tutorial	Tutorial 9
	Project	Lab Project (submission due)
Study Week: 25 April - 28 April	Lecture	Revision

Resources

Prescribed Resources

- Course Notes
- Reading Materials (papers, etc...)
- Lecture Slides

Recommended Resources

- Proakis & Manolakis, Digital Signal Processing: Principles, Algorithms and Applications, Prentice Hall.
- Simon Haykin, Modern Filters, Macmillan Publishing Company.
- Sanjit K. Mitra,Digital Signal Processing, A Computer-Based Approach, McGraw-Hill.
- Paulo S. R. Diniz, Eduardo A. B. da Silva and Sergio L. Netto, Digital Signal Processing, System Analysis and Design, Cambridge University Press.
- Bernard Mulgrew, Peter Grant, and John Thompson, Digital Signal Processing, Concepts and Applications, SpringerLink.

Course Evaluation and Development

Feedback will be gathered throughout the trimester both openly and anonymously. At the start of every lecture, the lecturer will ask students how they are progressing and if they have any questions. The lecturer will also has if they have any comments or suggestions. An anonymous feedback box will also be available throughout the trimester on Moodle for students to provide comments, suggestions and feedback.

Academic Honesty and Plagiarism

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.

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.

Academic Information

COVID19 - Important Health Related Notice

Your health and the health of those in your class is critically important. You must stay at home if you are sick or have been advised to self-isolate by NSW health or government authorities. Current alerts and a list of hotspots can be found here. **You will not be penalised for missing a face-to-face activity due to illness or a requirement to self-isolate**. We will work with you to ensure continuity of learning during your isolation and have plans in place for you to catch up on any content or learning activities you may miss. Where this might not be possible, an application for fee remission may be discussed.

If you are required to self-isolate and/or need emotional or financial support, please contact the Nucleus: Student Hub. If you are unable to complete an assessment, or attend a class with an attendance or participation requirement, please let your teacher know and apply for special consideration through the Special Consideration portal. To advise the University of a positive COVID-19 test result or if you suspect you have COVID-19 and are being tested, please fill in this form.

UNSW requires all staff and students to follow NSW Health advice. Any failure to act in accordance with that advice may amount to a breach of the Student Code of Conduct. Please refer to the Safe Return to Campus guide for students for more information on safe practices.

Dates to note

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

Student Responsibilities and Conduct

Students are expected to be familiar with and adhere to all UNSW policies (see https://student.unsw.edu.au/policy), 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 formal classes and *independent, self-directed study*. In periods where you 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.

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 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. Be aware of the "fit to sit/submit" rule which means that if you sit an exam or submit an assignment, you are declaring yourself well enough to do so and cannot later apply for Special Consideration. For more information and how to apply, see https://student.unsw.edu.au/special-consideration.

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

CRICOS

CRICOS Provider Code: 00098G

Acknowledgement of Country

We acknowledge the Bedegal people who are the traditional custodians of the lands on which UNSW Kensington campus is located.

Appendix: Engineers Australia (EA) Professional Engineer Competency Standard

Program Intended Learning Outcomes	
Knowledge and skill base	
PE1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline	✓
PE1.2 Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline	✓
PE1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline	✓
PE1.4 Discernment of knowledge development and research directions within the engineering discipline	✓
PE1.5 Knowledge of engineering design practice and contextual factors impacting the engineering discipline	
PE1.6 Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline	
Engineering application ability	
PE2.1 Application of established engineering methods to complex engineering 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	
Professional and personal attributes	
PE3.1 Ethical conduct and professional accountability	
PE3.2 Effective oral and written communication in 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	