ELEC3104
Digital Signal Processing

Course Outline – Semester 1, 2015

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

Course Staff

Course Convener: Prof. E. Ambikairajah, Room G8, e.ambikairajah@unsw.edu.au

Course & Lab Coordinator: Dr. Phu Le, Room 306, ngoc.le@unsw.edu.au
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Consultations: You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. All course and lab related emails should be directed to Dr. Phu Le in the first instance including consultations. Any email enquiry regarding the course should be made from your student email address with ELEC3104 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.

Course Summary

Contact Hours

The course consists of 3 hours of lectures, 1-hour of tutorials/consultation and a 2-hour laboratory session each week. These face-to-face hours are supplemented by pre-recorded lectures and pre-recorded sample problem solutions, which can be downloaded online - http://eemedia.ee.unsw.edu.au/ELEC3104/index.htm

Lectures	**Day**	**Time**	**Location**	**Name**
	Tuesday	1100-1300	Webst ThB	Prof. Ambikairajah
	Thursday	1100-1200	Ritchie Th	Dr. Phu Le
Tutorials	Wednesday	1700-1800	EE224	Prof. Dempster / Dr. Wijenayake
	Thursday	1200-1300	EE418	
	Thursday	1200-1300	Macauley Th	
	Thursday	1700-1800	EE224	

Context and Aims

Signal Processing is the process of measuring, manipulating or analysing information. Signals of interest include biomedical data, audio, still or moving images, radar, and even DNA. Filtering techniques can be crucial in revealing and interpreting information present in a signal. ELEC3104 Digital Signal Processing is an introductory signal processing course which takes students through the steps necessary to design and implement filters for a range of signals.

Aims

The course aims to equip students with:

- An Deduce and understand the behaviour of a system, in terms of both its time domain and frequency domain representations.
- Identify the correct type of filter required for a given problem and be able to demonstrate the design and implementation of a digital filter.
- Explain the concept of aliasing and its effect on the design of practical systems.
- Understand multi-rate processing and multi-rate systems.

Indicative Lecture Schedule

The indicative lecture schedule is listed in the following table. The corresponding video for that lecture also included in the table. Please note that the chapter numbers in the lecture notes and the chapter numbers in the pre-recorded lectures do not coincide, so the table below indicates which chapter corresponds to which pre-recorded lecture.

Week	Topic
1-2	Chapter 1: Signals and Systems **(Chapter 1 video)** [LO: 1, 2, 3]
	Chapter 2: Digital Signal Processing Fundamentals **(Chapter 5 video (mainly 5A))** [LO: 1, 2, 3]
	Chapter 3: Discrete-Time Systems (**Chapter 2 video**) [LO: 1, 2, 3]
	Chapter 6: Discrete-Time Fourier Transform (Mainly DFT) (**Chapter 6 video**) [LO: 1, 2, 3, 5]
3-5	Chapter 4: Introduction to z-Transform (**Chapter 3 video**) [LO: 1, 2, 3]
	Chapter 5: Introduction to Digital Filters (**Chapter 5 video (mainly 5B and 5C**)) [LO: 1, 2, 3, 4]
6	Chapter 6: Discrete-Time Fourier Transform (**Chapter 6 video**) [LO: 1, 2, 3, 5]
7	**Mid-semester Exam (Chapters 1-5): Tuesday, 21st April, 2014: 11am – 1pm**
7	Chapter 7: Analogue Filter Design (**Chapter 7 video**) [LO: 1, 2, 3, 4]
8-10	Chapter 8: Digital Filter Design (**Chapter 8 video**) [LO: 1, 2, 3, 4, 5]
11-12	Chapter 9: Multirate Digital Signal Processing (**Chapter 9 video**) [LO: 1, 2, 3, 4, 5, 7]
13	Revision
	Final Exam

Indicative Laboratory Schedule

Week	Suggested Lab work	Required Reading
4 & 5	Lab 1 – Signal Analysis [LO: 2, 3, 5]	Chapters 1, 2, & 6
6 & 7	Lab 2 – System Analysis [LO: 1, 2, 4, 5]	Chapters 1 - 5
8	**Lab Exam 1**	Chapters 1 - 6

9 & 10	Lab 3 – Filter Design [LO: 1, 2, 3, 4, 5, 6]	Chapters 1 - 8
11 & 12	Lab 4 – Multirate processing [LO: 2, 3, 5, 6, 7]	Chapters 1 - 9
13	**Lab Exam 2**	Chapters 1 - 9

Note: A laboratory manual, MATLAB exercises and a sample lab exam will be made available on the course Moodle.

Assessment

Mid-Semester Exam (1 hour and 30 minutes)	10%
Lab Exams (1 hour each + assessment time)	20%
Final Exam (3 hours)	70%

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 3rd year course in the School of Electrical Engineering and Telecommunications at the University of New South Wales. It is a core course for students following a BE (Electrical) or (Telecommunications) program and other combined degree programs, and an elective for Computer Engineering students.

Pre-requisites and Assumed Knowledge

The pre-requisite for this course is ELEC2134, Circuits and Signals. It is essential that students are familiar with basic circuit theory, signal analysis and transform methods. It is further assumed that students are familiar with the MATLAB environment, and have good computer literacy.

Following Courses

The course is a pre-requisite for all professional electives in the Signal Processing group, including ELEC4621 Advanced Digital Signal Processing and ELEC4622 Multimedia Signal Processing

Learning outcomes

At the end of the course students should:

1. Be able to apply transform methods to the analysis of analogue and digital linear time-invariant systems
2. Develop the appropriate competency in converting between time and frequency domain representations of signals and systems
3. Understand the practical aspects of sampling and reconstruction and be able to select a suitable sampling rate for a given signal processing problem
4. Design and analyse analogue and digital filters for a given specification
5. Demonstrate an understanding of the use and applications of the Discrete Fourier transform
6. Have gained practical experience with the implementation of digital filters
7. Be able to implement a simple multi-rate system

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

Processing and analysis of continuous (analogue) and discrete-time (digital) signals. Sampling continuous signals: the sampling theorem, reconstruction, aliasing and the z-transform. Analogue filters: Butterworth filters. Filter impulse and frequency responses, stability and digital oscillators. The Discrete Fourier Transform (DFT). Fundamentals of the design and realisation of finite impulse response (FIR) and infinite impulse response (IIR) digital filters. Linear and non-linear phase filters. Decimation, interpolation, multi-rate digital signal processing.

Teaching Strategies

Delivery Mode

This entire course will be delivered via live lectures and pre-recorded electronic whiteboard based lecture presentations. The live lectures will be supported by these pre-recorded lectures and pre-recorded sample problem solutions and you can watch these in your own time before the weekly lecture/discussion class. The advantages of the pre-recorded lectures are:

- You will be able to watch them at your own pace
- You can revisit the lecture content as many times as you like
- Things that you might miss in a normal live lecture (e.g. difficult mathematical concepts) are available on the video lectures and/or via the tutorial classes

Note that the laboratory material and the lecture material may not be entirely synchronised. The pre-recorded lectures on video provide you with an opportunity to cover material not yet covered in class. You should look through the laboratory notes to decide what material you need to look over.

Learning in this course

You are expected to attend <u>all</u> 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 do all your problem sheet questions (in the lecture notes) in advance of checking your answers against these solutions and attending the corresponding tutorial sessions. Group learning is encouraged.

Laboratory program

<u>The laboratory program is an important aspect of this course and will commence in Week 4</u>. Through the laboratory component, you will progressively encounter the elements of the syllabus. The aim of the laboratory component is to ground the analytical subject material in a real-world problem, where the skills and knowledge you learn throughout the course will be applied in real engineering design work. Throughout the semester, you will focus on:

- Sampling and reconstruction
- Impulse and frequency response of systems
- Description of filter types using poles and zeroes
- Digital filter design
- Frequency domain analysis
- Multi-rate processing

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 for Session 1, 2015 must take the labs.
If, for medical reasons, (note that a valid medical certificate must be provided) you are unable to attend a lab, please meet the co-ordinator (Dr. Phu Le) to discuss the situation.

Pre-requisite to pass the course
A satisfactory performance (50% or greater) in **each** of the following, is a necessary requirement to pass this course:

- **Lab exams**
- **Final Exam**

Assessment

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

Mid-Semester Exam (1 hour and 30 minutes)	10%
Lab Exams (1 hour each + assessment time)	20%
Final Exam (3 hours)	70%

Mid-Semester Examinations (10% total)
There will be one mid-semester examination, testing your understanding of the principles and your analytical skills through a number of set problems.

- Mid-Semester Exam: Tuesday, 21st April, 2015: 11am – 1pm
- Location of the exam will be confirmed prior to the exam
- Covers lecture material from Chapters 1 to 5

If for medical reasons (note that a valid medical certificate must be provided) or any other reasons, you are unable to attend the mid-semester exam, you will be given an oral examination of approximately 1 hour.

Laboratory Exams (20%)

During the semester, your progress in the laboratory will be assessed by your lab tutor based on two lab exams, the first of which will be in week 8 and the second in week 13 (during the regular lab sessions). The Laboratory Exams are open book practical exams that include MATLAB coding and analytical calculations. These exam questions will be based on what you have learned in your laboratory classes and lectures. **You must pass the lab exams to pass the course.**

NOTE: You **must attend all lab classes** in order to be able to sit the lab exam

Lab Exam 1	Friday, 1st May 2015	1 hour exam + 1 hour marking
Lab Exam 2	Friday, 5th June 2015	

Final Exam (70%)

There will be one final examination, testing your understanding of the principles and your analytical skills through a number of set problems. If for medical reasons, (note that a valid medical certificate must be provided to the university) you are unable to attend the final exam, you will be given another exam (either oral or written, at the discretion of the course convenor). **You must pass this final exam to pass the course.**

- The final exam will be 3 hours long
- The final exam consists of 5 questions (with many parts) and all of them must be answered

The final exam will cover all chapters covered in the semester

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes						
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mid-semester examination (10 %)	✓	✓	✓	-	✓	-	-
Lab exams (20%)	✓	✓	✓	✓	✓	✓	✓
Final examination (70%)	✓	✓	✓	✓	✓	-	✓

Course Resources

Textbooks

Prescribed textbook

S. K. Mitra, Digital Signal Processing, McGraw-Hill, 2011. This book is available at the UNSW bookshop and also available as an ebook - https://create.mheducation.com/shop/#/catalog/details/?isbn=9781308454726

Reference books

- J. Proakis & D. Manolakis, Digital Signal Processing, Prentice-Hall, 2007.
- A. V. Oppenheim, R. W. Schafer, & P. Buck, Discrete-Time Signal Processing, Prentice-Hall, 2010.

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

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 http://www.lc.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://my.unsw.edu.au/student/atoz/ABC.html), 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://my.unsw.edu.au/student/atoz/SpecialConsideration.html.

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 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:
http://www.engineering.unsw.edu.au/electrical-engineering/policies-and-procedures
https://my.unsw.edu.au/student/atoz/ABC.html

Important Points

Please note the following:

- During your labs, a lab demonstrator will be present and will be able to guide you in your laboratory-based learning.
- The lecture notes contain the course outline, tutorial problem sheets, a sample mid-semester exam, a sample final exam paper and references.
- Soft copies of the above (lecture notes) will be made available on the course Moodle.
- A laboratory manual, MATLAB exercises and a sample lab exam will be made available on the course Moodle.
- The pre-recorded lecture videos and tutorials can be downloaded from: http://eemedia.ee.unsw.edu.au/ELEC3104/index.htm For any problems with download etc, please contact, Dr. Phu Le on ngoc.le@unsw.edu.au
- Guidelines on learning that inform teaching at UNSW are available at www.guidelinesonlearning.unsw.edu.au

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:

- Analytical skills, critical thinking and creative problem solving will be developed by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Self-assessment of independent and reflective learning is made available through a series of tutorials spanning the duration of the course together with the video-based learning material. The laboratory program fosters independent learning.
- Demonstration of the understanding of principles, and the effective use and communication of relevant information will be tested in depth, via the mid-semester examination and the final examination.

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	