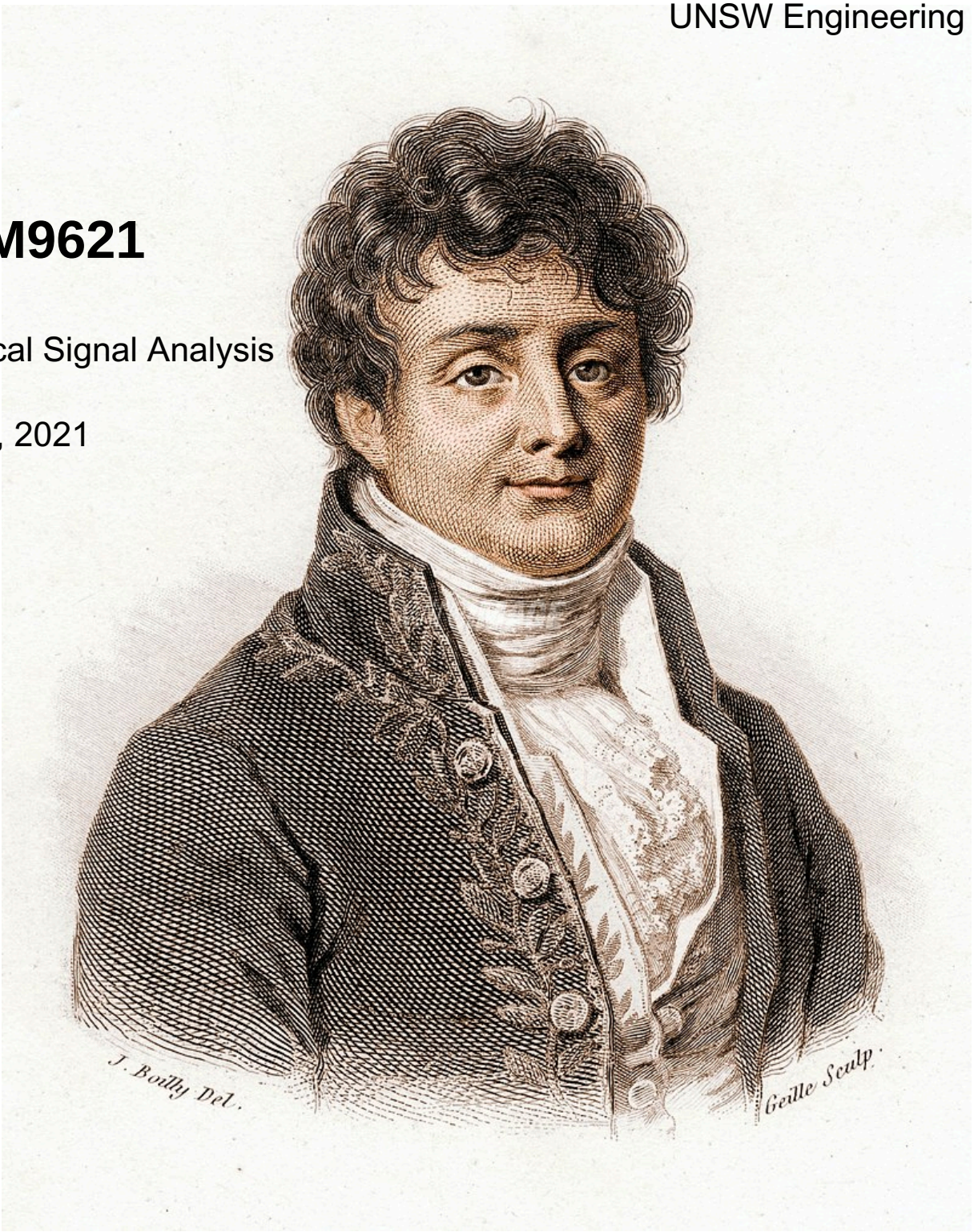
Graduate School of Biomedical Engineering

UNSW Engineering

BIOM9621

Biological Signal Analysis

Term 3, 2021



Course Overview

Staff Contact Details

Convenors

Name	Email	Availability	Location	Phone
Robert Nordon	r.nordon@unsw.edu.au	Email	Room 508, Level 5, Samuels Building	61 2 93850559

Lecturers

Name	Email	Availability	Location	Phone
Reza Argha	a.argha@unsw.edu.au	email		

School Contact Information

Student Services can be contacted via unsw.to/webforms.

Course Details

Units of Credit 6

Summary of the Course

The aim of biological signal analysis is to extract or reveal *useful* information from biological systems. These signals are generated by all living processes. All living things can interpret signals from the physical world. These signals can be electrical, acoustic, mechanical, chemical or optical in origin. The information from biological systems is used for research, diagnostics or control. The student will gain a general set of mathematical tools that will enable a deeper understanding of how biomedical devices and physiological systems work. The course is pitched at a general level to engineers from mechanical, electrical, chemical, computer science, material science and bioinformatics backgrounds, and will require an elementary background in calculus and complex numbers.

Course Aims

1. To gain a practical knowledge of how to record biological signals digitally without artefact
2. To analyse the frequency content of these signals and design digital filters to remove noise
3. To identify a biological system model by analysing system input and output signals
4. To have a working knowledge of the numerical tools required for signal analysis
5. Enhance a biomedical engineering student's design skills

Course Learning Outcomes

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

Learning Outcome	EA Stage 1 Competencies
1. Summarise the role of signal analysis in several biomedical applications	PE1.1, PE1.2, PE1.4, PE2.1
2. Explain the theory and mathematics concerning the practice of signal analysis	PE1.2
3. Acquire, simulate and display signals using Matlab and Simulink	PE2.1, PE2.2
4. Analyse the acquired data with respect to frequency content using Matlab	PE1.2
5. Avoid and minimise artefacts that can arise during data acquisition	PE1.3
6. Apply data acquisition and simulation software to basic biomedical devices	PE2.2

Teaching Strategies

Online activities	You will need to revise your mathematical skills early in the course. The online math revision

	activity is compulsory (2% of assessment). During the course you will also need to develop Matlab programming skills using Matlab onramp. You will be required to compete the Matlab quiz (2% of assessment).
Lectures	Each week there will be a short lecture of approximately one hour duration, followed by either a tutorial or a laboratory session (sometimes both).
Tutorials	The tutorial/laboratory session aims to teach you how to apply signal theory to practical problems.
Assessments	The assignment (15%) will help reinforce and extend your knowledge in analog and digital signal processing. We advise that you use the assignment to discover your areas of weakness so that you may study more effectively.
Laboratory Work	The practical component of this course will teach you how to use a signal generator, oscilloscope and simple RC circuit. You will also discover how to analyse the frequency content of a signal The two lab reports will be worth 16% of the assessment.
Group work	You will attempt to design a mechanical ventilator controller to support patients with Covid respiratory failure. In week 10 you will present your work to the class. You will also hand in individual reports.

Additional Course Information

Presumed knowledge and skills

It is expected that the student has completed one year of university mathematics or the equivalent. Integral calculus and complex numbers will play a particularly important role in the course. Some experience in computing (any language) is desirable but not required. Extensive instruction in using Matlab and Simulink will be provided.

How BIOM9621 relates to other courses

This course is offered in the various biomedical engineering masters programs. It complements BIOM9640 Biomedical Instrumentation and BIOM9650 Biosensors and Transducers.

BIOM9621 focuses on the data acquisition process itself, the conversion of a continuous electrical signal to digital form, and on some of the numerical methods used to analyse digital data.

BIOM9640 is an introduction to the physiological measurement of bioelectric phenomena and neurostimulation and the instrumentation involved. BIOM9650 examines the basic biosensors and transducers used to measure pressure, flow, volume and other physiological variables.

Course content

Introduction to biomedical signal analysis	What are biological signals?
	Some applications of biological signal analysis
	Overview of course
	Simulink and Matlab overview
Linear time invariant systems I	Maths revision
	Definition of a LTI system
	Response of the LTI system to an impulse
Linear time invariant systems II	ODE representation of a LTI system
	Solution by Laplace transform
	Definition of transfer function
	Convolution theorem for Laplace transforms
	Analogue filters
Continuous time Fourier transform	Definition
	Concept of time and frequency domains
	Fourier transform of special functions
	Convolution and Replication theorems
	Representation of a continuous signal as a delta train (shah function)
Digital sampling	Application of signal analysis theory to electrical signals
Discrete Fourier transform I	Representation of a continuous signal as a delta train (shah function)
	Definition (DFT versus DTFT)
	Convolution theorem
Discrete Fourier transform II	Introduction to ideal sampling
	Aliasing and Nyquist rate
	zero padding
	z-transform
Digital filtering I	Definition of FIR and IIR filters
	z-transform representation of a digital filter
	Definition of phase and power
	Frequency response of a digital filter
	Filter design methods
Spectrum estimation	Welch's periodogram
	Cross-correlation and autocorrelation
	Effect of sampling and noise on accuracy of spectral estimate
	Short-time Fourier transform
Application of signal analysis theory to biomedical systems	Black box polynomials models, Matlab’s System Identification toolbox

Assessment

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Online Maths and Matlab Revision Quizzes	4%	29/09/2021 12:00 AM	1, 2, 3, 4, 5, 6
2. Major topic online quizzes	50%	Not Applicable	2, 5
3. Lab reports	16%	10/11/2021 12:00 AM	2, 3, 4, 5, 6
4. Group project. Development of a mechanical ventilator controller to support respiratory failure in COVID patients	15%	Not Applicable	
5. Major Assignment	15%	17/11/2021 12:00 AM	2, 4, 5

Assessment 1: Online Maths and Matlab Revision Quizzes

Due date: 29/09/2021 12:00 AM

These quizzes will assess Maths and Matlab prerequisites for this course.

Assessment 2: Major topic online quizzes

There will be 5 online quizzes that will assess signal analysis theory covering 1) Linear time-invariant systems 1 2) Linear time-invariant systems 2 3) Fourier Transform 4) Digital Sampling 5) Z-transform and Digital Filtering. They will be based upon online learning activities for each of these major topics.

Online quizzes on 30-Sep, 7-Oct, 14-Oct, 28-Oct, 18-Nov (10-11 am)

Assessment 3: Lab reports

Due date: 10/11/2021 12:00 AM

There will be two lab reports (8 % each) based on analogue and digital signal processing labs. Unfortunately this year it won't be possible to have face-to-face practicals because of the COVID lockdown. I will be demonstrating the practical and forwarding the acquired data for you to analysis.

Assessment 4: Group project. Development of a mechanical ventilator controller to support respiratory failure in COVID patients

Students will form groups of 4 and select a medical problem to be solved (supplied). The aim of the project is to 1) develop a medical device concept that addresses the medical problem including user needs 2) evaluate one or more medical device concepts by applying biological signal analysis theory 3) simulate and evaluate medical device performance 4) present their finding to the class 5) prepare a group report that summarises the design process and its outcomes 6) prepare an individual report that

reflects upon the group's design and analysis process.

Assessment breakdown: Group presentation and report 8%, individual report 7%

Medical device design and analysis presentations 18-Nov (10 am-1 pm)

Medical device design and analysis group report 18-Nov (11:59 pm)

Medical device design and analysis individual report 22-Nov (11:59 pm).

Assessment criteria

Marking rubrics for the individual report

a) literature review for the allocated system (1 mark)

Criteria	Mark
Incomplete, low-quality presentation	0.5
Complete, high-quality presentation	1

b) application of signal analysis mathematical theory to the allocated system (1 mark)

Criteria	Mark
Partial analysis	0.5
Complete analysis	1
*Criteria for complete analysis: Is the system linear and time-invariant? What is the frequency response of the system? What is the impulse response of the system? How does the mathematical model relate to the physiological model	

c) description of the controller design and any testing (1 mark)

Criteria	Mark
No "closed-loop" controller design provided but has a comprehensive analysis of physiological response to manual control of ventilator	0.5
Closed-loop design provided with testing	1

d) verification of the system controller and the results of your simulation the 10 patient lung function signals (1 mark)

Criteria	Mark
x number of patients that survive for your simulations, M highest number of patients saved for all simulations, m lowest number of patients saved for all simulations	(x-m)/(M-m)

e) reflection on how well the team worked together including your role (1 mark)

Criteria	Mark
Does not provide roles and responsibilities of group members, and what was achieved as a group. No contribution to group work	0
Provides roles and responsibilities of group members and provides what each member contributed to the group output. Minor contribution to group work	0.5
Comments on potential shortcomings of teamwork and how to form an ‘ideal’ medical device R&D team in the future. A significant contribution to group work	1

f) additional analysis or refinement or value-add to the group’s output (slide show and shared material) conducted by yourself. (2 marks)

Criteria	Mark
Does not report what was shared between group members, and acknowledges the contribution of individual members	0
Resolves additional minor issues not solved by the group e.g., enhances literature review	1
Resolves additional major issues not solved by the group e.g., modified controller design to increase patient survival.	2

Assessment 5: Major Assignment

Due date: 17/11/2021 12:00 AM

The major assignment will be a combination of short and long answers covering material that is not assessed by online quizzes. It will be based on analysis of an ECG signal.

Attendance Requirements

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

Course Schedule

Contact hours	3 hours per week
Lecture	Thursday 10:00 am – 11:00 am (online)
Tutorial/Laboratory	Thursday 11:00 am – 1:00 pm (online)
Online Activities	3 hours

View class timetable

Timetable

Date	Type	Content
Week 1: 13 September - 17 September	Online Activity	Introduction to biomedical signal analysis (RN)
	Online Activity	Introduction to Matlab.
Week 2: 20 September - 24 September	Online Activity	Linear time-invariant systems I (RN)
	Online Activity	Introduction to Simulink I/O.
	Online Activity	Measure the frequency response for a low pass filter (demonstration)
Week 3: 27 September - 1 October	Online Activity	LTI 1 online quiz 10:00-11:00 am (10%)
	Online Activity	Linear time-invariant systems II (RN)
	Online Activity	Physical examples of LTI systems (Tutorial)
	Online Activity	Model the frequency response for a low pass filter (Demonstration).
Week 4: 4 October - 8 October	Online Activity	LTI 2 online quiz 10-11 am (10%)
	Online Activity	Continuous-time Fourier transform (RN)
	Online Activity	Simulation of the arterial pulse (Demonstration)
Week 5: 11 October - 15 October	Online Activity	Fourier Transform online quiz 10-11 am (10%)
	Online Activity	Digital sampling (RN)

	Online Activity	Digital acquisition of signals and frequency domain analysis (Tutorial)
	Online Activity	Estimate Fourier series coefficients for the arterial pulse waveform (demonstration)
Week 6: 18 October - 22 October	Online Activity	Medical Device Design (RN/RA)
	Group Work	Group formation, project selection (supplied) and allocation of roles and responsibilities. Acquisition of signal for the project (supplied).
Week 7: 25 October - 29 October	Online Activity	z-transform and introduction to digital filtering. Using Matlab to design digital filters (RA)
	Online Activity	Evaluating z-functions on the unit circle. DFT with zero-padding. Explore the effects of windowing. Ad-hoc filter design and difference equation implementation. FIR and IIR filter design. (Tutorial)
Week 8: 1 November - 5 November	Online Activity	PID control (RA). Using Matlab/Simulink to design and tune control system
	Online Activity	Ziegler-Nichols tuning of PID controllers (Tutorial)
	Online Activity	Matlab exercises (Practical)
Week 9: 8 November - 12 November	Online Activity	Sampling and spectral analysis of biological signals (RA)
	Online Activity	Periodogram and short time Fourier transform (tutorial)
	Online Activity	Digital sampling online quiz 10-11 am (10%)
Week 10: 15 November - 19 November	Group Activity	Medical Device Design and Analysis (group presentations) Groups present their medical device design concept and simulate its performance.
	Online Activity	z-transform and introduction and digital filtering online quiz 10-11 am (10%)

Resources

Prescribed Resources

All material will be provided via Moodle. Teams tutorials will be recorded.

Recommended Resources

DATES TO NOTE

Refer to MyUNSW for **Important Dates**.

PLAGIARISM

Beware! An assignment that includes plagiarised material will receive a 0% Fail, and students who plagiarise may fail the course. Students who plagiarise will have their names entered on plagiarism register and will be liable to disciplinary action, including exclusion from enrolment.

It is expected that all students must at all times submit their own work for assessment. Submitting the work or ideas of someone else without clearly acknowledging the source of borrowed material or ideas, is plagiarism.

All assessments which you hand in **must** have a **Non Plagiarism Declaration Cover Sheet**. This is for both individual and group work. Attach it to your assignment before submitting it to the Course Coordinator or at the School Office.

Plagiarism is the use of another person's work or ideas as if they were your own. When it is necessary or desirable to use other people's material you should adequately acknowledge whose words or ideas they are and where you found them (giving the complete reference details, including page number(s)). The Learning Centre provides further information on what constitutes Plagiarism at:

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

ACADEMIC ADVICE

Last year we had problems with contract cheating and 'sharing' of assignment answers which are very serious breaches of academic conduct. Please read the **student conduct policy** and the **academic misconduct procedure**. It is expected that students attend all lectures and tutorial sessions.

Assignments submitted after the due date without prior notification and permission will be subject to a deduction in marks.

UNSW has a wide range of student support services. The resources listed below should be used by students needing assistance related to aspects of their overall University experience. Specific help regarding this course can be sought from the course coordinator.

http://www.student.unsw.edu.au/

https://my.unsw.edu.au/student/howdoi/HowDoI_MainPage.html

http://www.counselling.unsw.edu.au/

Those students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course coordinator prior to, or at the commencement of, their course, or with **Disability Support Services**. Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.

If you believe that your performance in an assessable component of the course has been affected by illness or another unexpected circumstance, you should make an application for special consideration as soon as possible after the event by visiting UNSW Student Central. Please talk to the course coordinator as well and note that considerations are not granted automatically.

UNSW has strict policies and expectations relating to Occupational Health and Safety (OHS) accessed at **http://www.ohs.unsw.edu.au/**

Course Evaluation and Development

Student feedback has helped to shape and develop this course, including feedback obtained from on-line evaluations as part of UNSW's Course and Teaching Evaluation and Improvement (**MyExperience**) process. To discourage cheating and encourage independent problem-solving skills, we have increased the percentage of assessment contributed by the final exam.

Laboratory Workshop Information

Face-to-face labs will be replaced by online demonstrations. I will generate your data, which you will need to analyse for your individual reports.

Submission of Assessment Tasks

Laboratory reports and major assignments will require a Non Plagiarism Declaration Cover Sheet.

Late submissions will be penalised 10% of the mark for each calendar day late. If you foresee a problem in meeting the nominated submission date please contact the Course Convenor to make an appointment to discuss your situation as soon as possible.

Academic Honesty and Plagiarism

PLAGIARISM

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All assessments which you hand in must have a Non Plagiarism Declaration Cover Sheet. This is for both individual and group work. Attach it to your assignment before submitting it to the Course Coordinator or at the School Office.

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Academic Information

COURSE EVALUATION AND DEVELOPMENT

Student feedback has helped to shape and develop this course, including feedback obtained from on-line evaluations as part of UNSW's as part of UNSW's myExperience process. You are highly encouraged to complete such an on-line evaluation toward the end of Term. Feedback and suggestions provided will be important in improving the course for future students.

DATES TO NOTE

Refer to MyUNSW for Important Dates, available at:
https://my.unsw.edu.au/student/resources/KeyDates.html

ACADEMIC ADVICE

For information about:

- Notes on assessments and plagiarism,
- Special Considerations,
- School Student Ethics Officer, and
- BESS

refer to the School website available at
http://www.engineering.unsw.edu.au/biomedical-engineering/

Supplementary Examinations:

Supplementary Examinations for Term 3 2021 will be held on Monday 10th January – Friday 14th January (inclusive) should you be required to sit one.

Image Credit

Engraved portrait of French mathematician Jean Baptiste Joseph Fourier (1768 - 1830), early 19th century.

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	