School of Electrical Engineering and Telecommunications

Term 3, 2019
Course Outline

ELEC4623
BIOMEDICAL INSTRUMENTATION, MEASUREMENT AND DESIGN

COURSE STAFF

Course Convener: Dr. Reza Argha, Room 338, a.argha@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. Lecturer consultation times will be advised during lectures. 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/TELE4623 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 2 or 3 hours of lecture per week, 3 hours of laboratory session in 5 selected weeks, 1 hour of tutorial in 4 selected weeks.

	Day	Time	Location
Lectures	Tuesday	Week 1-4: 3-6pm Week 5-10: 3-5pm	CivEng G1
Labs	Thursday	9am - 12noon Week 2,4,6,8,10	ElecEng224
Tutorials	Friday	1pm – 2pm Week 4,6,8,10	AinswthG01

Context and Aims

The aim of this course is to make the student familiar with the design and development of biomedical instrumentation for clinical measurement and biomedical research. The course will focus strongly on hardware and software design issues required to produce instruments, which satisfy Australian and International standards for safety, performance and quality control. Through this course, the student will be equipped with the fundamental knowledge required to become a professional engineer in the field of biomedical instrumentation.

A number of key concepts in bioinstrumentation development will be covered by this course; including the principles and operation of biopotential electrodes and biomedical sensors; the design of biopotential amplifiers for measurement of electrocardiogram (ECG); safety and performance standards for medical instrumentation; biomedical signal processing; and special topics on the measurement of blood pressure/flow and respiration.

This course is designed for students with an electrical engineering background, and students who undertake this course are not expected to have prior knowledge in human physiology and biology. Although students will learn some basic knowledge about human physiology and cardiovascular system from this course, the main focus is on the technical aspects of instrumentation design and signal processing.

Indicative Lecture Schedule

Period	Summary of Lecture Program
Week 1	Introduction to biomedical instrumentation and physiological measurement. The origin of biopotentials and other biological signals. Biopotential electrodes and tissue equivalent circuits.
Week 2	Characteristics of biological and instrumentation noise. Practical biopotential amplifier design and multilead ECG systems.
Week 3	Principles and operation of basic transducers and sensors.
Week 4	Biological signal processing – digital filter design.
Week 5	Statistical algorithms for automated signal detection and analysis. * Release of Assignment.
Week 6	Circulatory system and the measurement of blood pressure and blood flow.
Week 7	The measurement of respiratory flows.
Week 8	Safety and performance standards (ASA, IEC and FDA) for medical instrumentation
Week 9	Principles of ultrasound imaging.
Week 10	Project presentations and submission of project report. * Assignment Due.

Indicative Laboratory Schedule

Period	Summary of Laboratory Program
Week 2	Use of the Telemonitoring system to record vital signs – No report, attendance is compulsory!
Week 4	Electrical Characteristics of biopotential electrodes.
Week 6	Design, testing and analysis of a high quality isolated biopotential amplifier.
Week 8	Frequency response of BP measurement system + Respiratory flows.
Week 10	Electrical Safety Testing of Biomedical Equipment – No report, attendance is compulsory!

Assessment

Laboratory Practical Experiments	20%
Project Seminar	10%
Assignment	20%
Final Exam (2 hours)	50%

COURSE DETAILS

Credits

This is a 6 UoC course and the expected workload is 5 hours per week throughout the 10 week term.

Relationship to Other Courses

This course is offered as a professional elective course in the fourth year of the Electrical Engineering degree or in the postgraduate program.

Pre-requisites and Assumed Knowledge

ELEC/TELE 3104 Digital Signal Processing (or equivalent)

ELEC/TELE 3114 Systems and Controls 1 (or equivalent)

* For postgraduate students who did not take the above subjects in UNSW, please make sure that you have taken the equivalent subjects in your universities.

Learning outcomes

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

1- Appreciate the issues and considerations involved in the design and development of biomedical instrumentation for clinical measurement and biomedical research
2- Understand the basic principles and operation of biopotential electrodes and biomedical sensors
3- Design a biopotential amplifier for ECG measurement
4- Consider the need to satisfy safety and performance standards in the development of medical instrumentation
5- Develop skills in biomedical signal processing using Matlab

It is hoped that students will also develop a strong interest in the research and development of biomedical instrumentation upon the completion of this course.

This course is designed to provide the above learning outcomes that arise from targeted graduate capabilities listed in **Appendix A**. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate attributes (listed in **Appendix B**). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in **Appendix C**.

Syllabus

Introduction to Biomedical Instrumentation and Physiological Measurement. The nature of biomedical signals. The origin of biopotentials and other biological signals. Biopotential electrodes. Tissue equivalent circuits. Principles and operation of basic transducers and sensors. Sources and characteristics of biological and instrumentation noise. Interference coupling. Use of ground and shields for reducing interference noise. ECG lead systems and waveforms. Design of a practical ECG preamplifier. Safety and performance standards (ASA, IEC and FDA) for medical instrumentation. Biological signal processing. Analogue and digital filters. Effect of filter characteristics on waveform morphometry. Statistical and algorithmic methods for automated signal detection and analysis. The measurement of blood pressure and flow. The measurement of respiratory flow. Design case study: Hot wire anemometry for respiratory flow measurement.

TEACHING STRATEGIES

Delivery Mode

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

- Formal face-to-face lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
- Tutorials, which allow for exercises in problem solving and allow time for you to resolve problems in understanding of lecture material;
- Laboratory sessions, which support the formal lecture material and also provide you with practical construction, measurement and debugging skills;

Learning in this course

You are expected to attend all lectures, tutorials, and labs, 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, 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. In addition, during the tutorial class, 1-2 new questions that are not in your notes may be provided by the tutor, for you to try in class. These questions and solutions may not be made available on the web, so it is worthwhile for you to attend your tutorial classes to gain maximum benefit from this course.

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 are required to attend laboratory at the selected weeks. Laboratory attendance WILL be kept, and you MUST attend at least 80% of labs.

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 intention to assess your learning progress through the term.

Laboratory Assessment

Laboratories are primarily about learning, and the laboratory assessment is designed mainly to check your knowledge as you progress through each stage of the laboratory tasks. You are required to maintain a lab book for recording your observations. A lab book is an A4 size notebook containing a mix of plain pages and graph sheets. You have to purchase your own lab book from any stores.

It is essential that you complete the laboratory preparation before coming to the lab. You are required to write the aim of the experiment and draw the circuit diagram if any in your lab book. This will be verified and signed by your demonstrators in the lab. You will be recording your observations/readings in your lab book first and then completing and submitting the results sheet before leaving the lab.

After completing each experiment, your work will be assessed by the laboratory demonstrator. Both the results sheet and your lab book will be assessed by the laboratory demonstrator.

Assessment marks will be awarded according to your preparation (completing set preparation exercises and correctness of these or readiness for the lab in terms of pre-reading), how much of the lab you were able to complete, your understanding of the experiments conducted during the lab, the quality of the code you write during your lab work (according to the guidelines given in lectures), and your understanding of the topic covered by the lab.

Assignment

The assignment allows self-directed study leading to the solution of partly structured problems. Marks will be assigned according to how completely and correctly the problems have been addressed, the quality of the code written for the assignment (must be attached to the report), and the understanding of the course material demonstrated by the report.

The assignment report will be due at the Tuesday lecture in Week 10. *Late reports will attract a penalty of 10% per day* (including weekends).

Final Exam

The exam in this course is a standard closed-book 2 hours written examination. 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**
Laboratory practical assessments	✓	✓	✓	✓	✓
Assignment	✓	✓	-	-	✓
Final exam	✓	✓	✓	✓	-

COURSE RESOURCES

Textbooks

Prescribed textbook

- Medical Instrumentation - Application and Design, (3rd or 4th Edition), John G. Webster, editor: John Wiley and Sons Inc. ISBN0471153680 (available in UNSW Library)
- R. O. Duda, P. E. Hart, D. G. Stork, Pattern Classification, 2nd Edition, Wiley, 2000. (Covers supervised classification), ILS API ID: 61UNSW_INST51216337500001731 (available in UNSW Library)

Reference books

- Alexander, C. K., Sadiku, M. N. O., Fundamentals of Electric Circuits, McGraw Hill, 3rd edition.
- Dorf, R. C., Svoboda J. A., Introduction to Electric Circuits. Wiley, 6th ed., 2004.
- G. F. Franklin, J. D. Powell, and A. Emami-Naeini, Feedback Control of Dynamic Systems, Addison Wesley, 1994.
- S. K. Mitra, Digital Signal Processing, MrGraw-Hill, 2006.
- J. Proakis and D. Manolakis, Digital Signal Processing, Prentice-Hall, 1996.
- V. Oppenheim, R. W. Schafer, and P. Buck, Discrete-time Signal Processing, Prentice-Hall, 1999.

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 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. 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.

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

APPENDICES

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows

- Developing scholars who have a deep understanding of their discipline, through lectures and solution of analytical problems in tutorials and assessed by assignments and written examinations.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.
- Developing digital and information literacy and lifelong learning skills through assignment work.

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	✓

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SUGGESTED PROJECT TOPICS

1. Digital filters for elimination of 50 Hz noise from ECG recordings
2. Automated QRS detection from ECG
3. Automated pulse detection from arterial pressure or PPG waveform
4. Techniques and designs for minimization/identification of motion artefact (artifact) in ECG / PPG / arterial pressure
5. Application of machine learning / rule-based expert systems for diagnostic interpretation of the clinical (12 lead) ECG
6. Biomedical signal processing - A review of frequency spectrum analysis techniques including FFT, AR, cross-spectrum, coherence
7. Frequency domain spectral analysis of heart rate variability
8. Frequency domain spectral analysis of blood pressure variability
9. Nonlinear time series analysis of heart rate variability
10. Biomedical application of piezoelectric sensors (examples: accelerometry for motion, posture and energy expenditure, microphone for heart sound)
11. Biomedical application of absorption spectroscopy (examples: pulse oximetry, near infrared spectroscopy for O_2, capnography for CO_2)
12. Biomedical application of bioimpedance / impedance plethysmography (examples: fluid content, body fat)
13. A commercial ECG monitor (examples: PageWriter ECG cart, ECG recorder from Nikhon Cohden, Siemens, Marquette)
14. A technique/product for automated non-invasive measurement of blood pressure (examples: oscillometric, auscultatory)
15. A technique/product for non-invasive continuous measurement of blood pressure (examples: arterial tonometer, Finapres / Portapres)

16. A technique/product for non-invasive measurement of cardiac output (examples: Doppler ultrasound, impedance cardiography / thoracic bioimpedance, arterial pulse contour e.g. Modelflow)
17. A technique/product for non-invasive measurement of arterial pulse wave velocity (examples: Sphygmocor, Complior)
18. A technique/product for measurement of peripheral blood flow / volume (examples: Laser Doppler flowmetry, venous-occlusion plethysmography)
19. A technique/product for respiratory measurement (examples: spirometer, gas analyzer, inductance plethysmography)
20. A technique/product for body temperature measurement (examples: Non-contact infra-red measurement of tympanic temperature)
21. Non-invasive blood glucose monitoring
22. Wearable biosensor (examples: PPG ring sensor by MIT, forehead pulse oximeter, Lifeshirt)
23. Application of wireless sensor network in mobile physiological monitoring

The approach to these topics will in general involve some library / internet research to source material, including books, journals and conference papers. A good review paper / book chapter will be an ideal starting point. Some useful search engines include Google, PubMed (http://www.ncbi.nlm.nih.gov/pubmed/) and IEEE Xplore (http://ieeexplore.ieee.org/Xplore/dynhome.jsp).