ELEC4623/ELEC9734
BIOMEDICAL INSTRUMENTATION, MEASUREMENT AND DESIGN

Course Outline – Session 2, 2009

COURSE STAFF

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Qim Yi Lee

COURSE DETAILS

Credits: 6 UoC course.

Contact hours: 2 hours of lecture per week.
3 hours of laboratory session in selected weeks.

Lectures: Tuesday 6:00-8:00 pm CivEng G1
Lab sessions: Wednesday 6:00-9:00 pm EE201/EE214

COURSE INFORMATION

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.

**Relation 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. The subject is compulsory for combined BE/MBiomedE and CE/MBiomedE students.

**Pre-requisites:**
- ELEC3104 Digital Signal Processing (or equivalent)
- ELEC3114 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.

**Assumed knowledge:**
- Basic knowledge about circuitry design, as covered in ELEC2134 Circuits and Signals (including Kirchhoff’s Law, Thevenin and Norton equivalents, Op-Amps);
- Knowledge about digital filtering and basic programming skills in Matlab for signal processing, as covered in ELEC3104 Digital Signal Processing;
- Basic knowledge about frequency response (Bode plots) and stability of systems, as covered in ELEC3114 Systems and Controls 1.

**LEARNING OUTCOMES**

After the successful completion of the course, the student should be able to:
- Appreciate the issues and considerations involved in the design and development of biomedical instrumentation for clinical measurement and biomedical research
- Understand the basic principles and operation of biopotential electrodes and biomedical sensors
- Design a biopotential amplifier for ECG measurement
- Consider the need to satisfy safety and performance standards in the development of medical instrumentation
- 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.

The course delivery methods and course content address a number of core UNSW graduate attributes; these include:
- The capacity for analytical and critical thinking and for creative problem-solving, which is addressed by the laboratory work and the project task.
The ability to engage in independent and reflective learning, which is addressed by the laboratory work and the project task.

- Information literacy, which is addressed by the laboratory reports.
- The skills of effective communication, which are addressed by the laboratory reports.

Please refer to [http://www.ltu.unsw.edu.au/content/userDocs/GradAttrEng.pdf](http://www.ltu.unsw.edu.au/content/userDocs/GradAttrEng.pdf) for more information about graduate attributes.

**TEACHING STRATEGIES**

The course consists of lectures, laboratories, an assignment and a design project/case study.

**Lectures** The lectures are intended to provide explanations and elaborations of the core subject material. The lecture presentation will be in the form of PowerPoint slides, which will be made available to the students. Since the course covers a wide range of topics, it is essential that students attend the lectures to gain a deep understanding on the critical elements of the course, which will be important for success in the final exam.

**Laboratories** The laboratories will be closely integrated with the lectures. They are intended to provide students with practical experience in testing the performance of biopotential electrodes (e.g. Ag/AgCl electrodes), designing and testing a high performance ECG biopotential amplifier, writing Matlab programs to perform signal processing on biomedical signals such as ECG, and testing electrical equipment against safety standards. Although some of the laboratory tasks involve hardware, the students are not required to build circuitry in these tasks and will only need to learn how to use and make connections in the equipment provided. The laboratories can help to enhance the general understanding of the course content and its application in practice.

**Assignment** The assignment consists of short answer questions that are designed to test the students’ understanding of subject material and help them to prepare for the exam.

**Project** The project for this course is a design case study, in which the student is expected to demonstrate skills in literature review and critical understanding of a biomedical product or technique. A PowerPoint presentation of the project findings will be required, which provides a chance for the student to learn how to effectively communicate their findings to the class.
**ASSESSMENT**

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<tr>
<th>Component</th>
<th>Percentage</th>
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<tr>
<td>LABORATORIES (3 lab reports)</td>
<td>25%</td>
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<tr>
<td>PROJECT SEMINAR</td>
<td>10%</td>
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<td>ASSIGNMENT</td>
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<tr>
<td>FINAL EXAMINATION</td>
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<td><strong>Total</strong></td>
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**Laboratories**  
The laboratory work will be performed by each group of two students in the allocated lab times. The students are expected to complete the laboratory work within the three-hour lab session (except for lab 5, in which each student performs the computer work individually and may choose to do it in his/her own time). Each student will need to submit a report individually, about two weeks’ after the laboratory session. Plagiarism (as indicated by very similar wording and presentation) will result in zero mark for both reports. A good lab report should include the following:

- Brief description of the purpose of each test and what has been done in your own words (please avoid direct duplication of large volume of material in the lab manual)
- Presentation of the results (tables and graphs may help) and in some cases, derivation of the results
- Discussion of the results with emphasis on key concepts presented in lectures and whether the results agree with theoretical expectations
- Answers to the questions mentioned in the lab manual

The assessment will be based on quality not quantity of the work done. A concise report which addresses the key points will be marked more favorably compared with a lengthy report with irrelevant or trivial material. Lab 3 and Lab 5 are each worth 10%, while Lab 2 is worth 5% of the final mark.

**Project seminar**  
A different design case study will be selected by each project group of two students. Please see the attached pages for the possible topics. You are also free to propose your own topic (with approval from your lecturer). For the topics involving a review of methods (e.g. signal processing), you are expected to provide some theoretical background and explain how the methods are applied in practice, by citing relevant literature (e.g. conference or journal papers). For the topics involving an evaluation of a technique/product, you are expected to provide an in-depth critical evaluation, which includes some understanding of the underlying theory (with cited literature) and how it is designed/implemented in practice, in a commercial product. A cursory review of the technique, or a direct copy of the wordings from websites/papers, is NOT acceptable. Assessment will be based on a 10-15 minute PowerPoint presentation in a seminar.

**Assignment**  
The assignment consists of short answer questions to be completed by students at home. It will be handed out to the student before the mid-session break.

**Final exam**  
The exam is a standard closed-book 3 hours written examination. Details will be provided towards the end of the course.
**RESOURCES FOR STUDENTS**

**Recommended textbook**

Medical Instrumentation - Application and Design, (3rd Edition)
John G. Webster, editor: John Wiley and Sons Inc.

**Books covering assumed knowledge**


**On-line resources**

Course material will be made available on Vista / WebCT (http://vista.elearning.unsw.edu.au)

**COURSE CONTENTS**

**OTHER MATTERS**

**Academic Honesty and Plagiarism**

Plagiarism is the unacknowledged use of other peoples’ work, including copying of assignment works and laboratory results from other students. Plagiarism is considered a serious offence by the University and severe penalties may apply. For more information about plagiarism, please refer to:

http://www.lc.unsw.edu.au/plagiarism

**Continual Course Improvement**

Students are advised that the course is under constant revision in order to improve the learning outcomes of its 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.

**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 policies, see:

http://scoff.ee.unsw.edu.au
# BRIEF SYLLABUS 2009

## WEEK 1  Starts Monday 20th July

Lecture 1: Introduction to Biomedical Instrumentation and Physiological Measurement.

Lecture 2: The origin of biopotentials and other biological signals.

## WEEK 2  Starts Monday 27th August

Lecture 3 & 4: Biopotential electrodes and Tissue equivalent circuits.

## WEEK 3  Starts Monday 3rd August

Lecture 5 & 6: Principles and operation of basic transducers and sensors.

Lab. 1: Use of the TeleMedCare system to record vital signs, presented by Prof. Branko Celler. (Wed 6-9pm) *(No laboratory report required)*

## WEEK 4  Starts Monday 10th August

Lecture 7 & 8: Characteristics of biological and instrumentation noise.

Lab. 2: Electrical characteristics of biopotential electrodes. (Wed 6-9pm)

## WEEK 5  Starts Monday 17th August

Lecture 7 & 8: (Continued)

Lecture 9 & 10: Practical biopotential amplifier design and multilead ECG systems.

## WEEK 6  Starts Monday 24th August

Lecture 9 & 10: (Continued)

Lab. 3: Design, testing and analysis of a high quality isolated biopotential amplifier. (Wed 6-9pm)

## WEEK 7  Starts Monday 31st August

Lecture 13 & 14: Biological signal processing – filters. (Lectures 11 & 12 moved to end)

## RECESS  Starts Monday 7th September
**WEEK 8  Starts Monday 14th September**

Lecture 15 & 16: Statistical algorithms for automated signal detection and analysis.

Lecture 17 & 18: Circulatory system and the measurement of blood pressure and flow.

Lab. 5: Design of analogue and digital filters for processing of biomedical signals. (Wed 6-9pm - in Computer Room 214, ElecEng)

* Assignment is due on this week

**WEEK 9  Starts Monday 21st September**

Lecture 17 & 18: (Continued)

Lab. 5: (Continued)

**WEEK 10  Starts Monday 28th September**

Lecture 19: The measurement of respiratory flows.

Lecture 20: Design case Study: Hot wire anemometry.

**WEEK 11  Starts Monday 5th October**

Lecture 11&12: Safety and performance standards (ASA, IEC and FDA) for medical instrumentation.

Lab. 4: Electrical safety testing of Biomedical instruments to AS3200.1, AS3003 and AS3551 standards (Wed 6-9pm)

(No laboratory report required but attendance is compulsory)

**WEEK 12  Starts Monday 12th October**

Lecture period devoted to Project presentations.

**WEEK 13  Starts Monday 19th October**

Lecture period devoted to Project presentations.
SUGGESTED PROJECT TOPICS

1. Digital filters for elimination of 50Hz noise from ECG recording
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 O₂, capnography for CO₂)
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).
**ENROLMENT FORM FOR PROJECTS Year 2009**

**PLEASE SUBMIT BY END OF WEEK 4**

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<tr>
<th>STUDENT NAMES (2 per Group)</th>
<th>TOPIC NUMBER or OTHER PROJECT TITLE (in order of preference)</th>
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* Different products/techniques under the same category are considered as separate preferences. Please also indicate the name of the specific product/technique that you are evaluating.