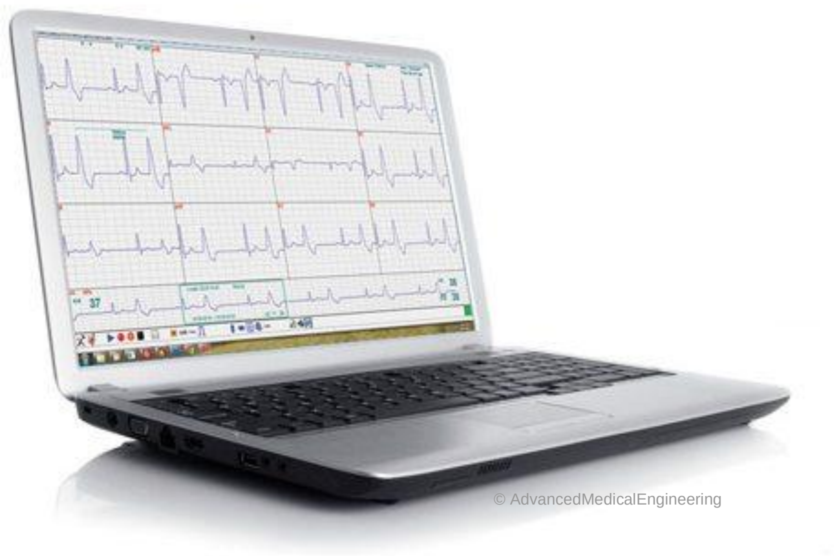
Teaching Plan

Course name: **Bioinstrumentation and Biosensors** (Bioinstrumentació i Biosensors)



Academic year: 2014-2015
Trimester: 1st

Degree: Bachelor's degree in Biomedical Engineering
Year: 3rd

Course code: 22129

Number of ECTS credits: 5
Hours of student work: 125

Language in which the course is taught: English

Teachers: Antoni Ivorra
Responsible professor: Antoni Ivorra

1. Course descriptors

Course name: Bioinstrumentation and Biosensors (Bioinstrumentació I Biosensors)

Course acronym: BIS

Academic year: 2014-2015
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Degrees: Bachelor's degree in Biomedical Engineering
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Course code: 22129

Number of ECTS credits: 5
Hours of student work: 125

Language(s) in which the course is taught: English (all written materials). Exceptionally, if students unanimously agree, lectures will be taught in Catalan or Spanish.

Teachers: Antoni Ivorra antoni.ivorra@upf.edu

Lab assistant: Genís Caminal genis.caminal@upf.edu

Responsible professor: Antoni Ivorra

2. Course presentation

This course mostly deals with theoretical and practical aspects regarding the acquisition of numerical data and signals from human body by means of electrodes and electronic sensors. The course aims three main teaching objectives: 1- to overview the fundamental features of modern medical measurement systems and the mathematical, physical and electronic foundations of those systems, 2- to introduce the **principles of design for electronic circuits** capable of safely interfacing electronic sensors and electrodes to digital systems and 3- to put in practice the above knowledge – and to get some lab and hardware prototyping skills – by implementing and testing a simple medical measurement system. In addition, some therapeutic uses of electricity will be shortly overviewed.

Short syllabus: Introduction to measurement systems, overview of circuit theory fundamentals, biomedical electrodes and electrochemical sensors, overview of modern electronic technology and physical sensors, signal conditioning circuits based on operational amplifiers and instrumentation amplifiers, analog-to-digital converters, biopotential recording systems, therapeutic uses of electricity.

Prerequisites: 1- very basic knowledge of circuit theory (i.e. Ohm's law, Kirchhoff's circuit laws, RC circuits charge and discharge equations, …), 2- undergrad level general physics (e.g. physics first year course in any engineering discipline), 3- signal theory basics (i.e. Fourier transform and sampling theory), 4- very basic probability theory and statistics (i.e. variance, probability density functions, confidence interval…) and 5- Matlab programming basics. In terms of courses from the Bachelor's degree in Biomedical Engineering at the UPF: "Bioelectromagnetisme", "Teoria de Senyals i Sistemes", "Biomodelatge Matemàtic II" i "Tècniques Computacionals en Biomedicina".

3. Competences the course aims to teach or to train

Transversal competences	Specific competences
Instrumental **INS1.** Ability for analysis and synthesis **INS2.** Organization and planning ability **INS3.** Ability for applying knowledge in practice **INS7.** Oral and written communication in English in academic or professional environments. **Interpersonal** **INT1**. Teamwork **Systemic** **SIS1.** Ability for applying flexibly and creatively the acquired knowledge to new scenarios. **SIS4.** Concern for quality	**Professional specific competences** **B1.** Ability for solving mathematical problems which may appear in engineering. Aptitude for applying knowledge on: linear algebra; geometry; differential geometry; differential and integral calculus; differential equations; numerical methods; numerical algorithms; and statistics. **B2.** Ability to use and program computers. Ability to use diverse operating systems, data bases and computer programs intended for engineering. **B6.** Knowledge on linear systems, circuit theory, electronic circuits, electronic and photonic devices, materials technology. **P1.** Ability for engineering projects preparation and development **P5.** Knowledge for taking measurements, performing calculations, technical reports, task planning and other analogous tasks. **Fundamental learning specific competences** **IB1.** Development and implementation of techniques for computational analysis of multimodal signals and images for diagnosis and monitoring. **IB2.** Design and development of technologies for acquisition, processing, modeling, visualization and interpretation of biological signals and physiological and clinical variables that can be used for medical prevention, diagnosis, treatment and rehabilitation. **IB3.** To understand the main physiopathological mechanisms and to computationally model the diverse organ systems of the human body, with emphasis on the cardiovascular system, the nervous system and the locomotor system. **IB7.** To understand and to distinguish diverse techniques and systems for biomedical signals and images which are capable of providing both structural and functional information from multiple biological and physiological processes. **Other competences** **O1.** Ability for implementing simple electronic circuit prototypes based on discrete components. **O2.** Ability for performing circuit analysis using a SPICE simulator.

4. Contents

Contents module identifier	Contents module title and main topics
Module 1 (**M1**)	**Introduction to measurement systems** - Sensors and transducers (definitions and main concepts) - General architecture of modern data acquisition systems - Measurement systems characteristics (Accuracy, Precision, Repeatibility, Reproducibility, Resolution, Range, Span, Linearity, Transfer function, Sensitivity, Hysteresis, Drift, Selectivity) - Calibration and systematic and random errors - Measurement systems dynamics - Reporting uncertainty
Module 2 (**M2**)	**Circuit theory fundamentals** - Physical meaning of voltage and current. Ideal sources. Thermopiles. - Ohm's law - Kirchhoff's circuit laws - Voltage dividers - Potentiometers - Superposition of independent sources - Equivalent circuits - Diodes - Transformers - Time transients in RC circuits - Impedance - Transfer function (frequency analysis) - Noise - Capacitively coupled interferences - Inductively coupled interferences - Simple passive filters - Electrical Safety (Electrical shock hazards, Macroshock and Microshock, Prevention of electrical hazards, Isolation)
Module 3 (**M3**)	**Signal conditioning circuits and analog-to-digital conversion** - Ideal operation amplifier (OA) - Inverting and non-inverting OA configurations - Common mode voltage and differential voltage - Output voltage saturation - Differential amplifier configuration - Instrumentation amplifier - Wheatstone bridge - Strain gauges - Pressure sensors - Blood pressure monitors - Isolation - Single supply OAs - Limitations of real OAs (offset voltage, bias currents, PSRR, CMRR, bandwidth, slew rate) - Multiplexors - Quantification errors - Sample-and-hold - ADCs architectures - Digital sensors
Module 4 (**M4**)	**Electrodes** - Electrolytes - Galvanic cells - Ion Selective Electrodes - Double-layer - Polarizable and non-polarizable electrodes - Electrical models for electrodes - Recording electrodes, stimulation electrodes

Module 5 (**M5**)	**Overview of modern electronic technology** - Valve diodes and triodes - Semiconductors - Thermistors - PN junction, diodes - PN temperature sensors - LED, photodiode - Pulse oximeter - MOS transistor, digital CMOS circuits - Microelectronics fabrication
Module 6 (**M6**)	**Overview of therapeutic uses of electricity** - Electrical stimulation of excitable tissues - Pacemakers, defibrillation - Cochlear implants, Functional Electrical Stimulation (FES) - RF ablation - Irreversible electroporation
Module 7 (**M7**) (Laboratory)	**Laboratory** - Arduino microcontroller platform and its interface to MATLAB - Acquisition and representation of DC and AC signals with Arduino + Matlab - Fabrication of a flow transducer - Design, SPICE simulation and physical implementation of signal conditioning electronics for differential pressure sensing. - Design and implementation of MATLAB code for spirometry - Calibration, test and characterization of the implemented spirometry system

5. Methodology

This course follows a conventional academic structure in which lectures and problem solving seminars are combined with short tests – for feedback purposes – and a final written exam. In addition, five supervised laboratory sessions will be conducted.

Lectures and problem solving seminars. Contents modules M1 to M3 will be taught in a conventional manner. That is, lectures on theoretical and practical aspects, together with examples of solutions to problems, will be given by the professor. In seminars exclusively devoted to problem solving, the students will have the opportunity to interactively participate in the class.

Modules M4, M5 and M6 correspond to topics that are to be learnt by heart and, therefore, no problem solving seminars are devoted to them.

Lab sessions. The five supervised lab sessions, of two hours each, are aimed towards the development and characterization of a spirometry system (sensor + electronics + software).

The first two lab sessions – in which the Arduino platform and its interface with Matlab are introduced as a data acquisition system of unspecified application – will be fully guided. That is, the students will have to follow a lab guide in which all the consecutive steps for performing the circuits, the measurements and the software will be detailed. These two guided lab sessions will require that the students study in advance some specific materials contained or indicated in the lab guide. Such previous study will not be tested directly at the beginning of the sessions but it will be assessed in a short multiple-choice test at the end of the second lab session (AL1). No report will be required for any of these two guided lab sessions

The other three supervised lab sessions will be truly devoted to the development of the spirometry system. The first one (and a half) of these sessions – in which the sensing system and the electronics will be simulated and built – will be guided but the other two will only be loosely supervised. It is expected that each team comes with original implementations concerning software and system characterization. Performance of the implemented system will have to be demonstrated at the end of the fifth session. Two extra unsupervised lab sessions are allocated so that students can freely work on their developments with all lab resources at their disposal. No report will be required.

At the last lab session, in addition to the assessment of the spirometry system, an execution test will be performed to individually asses the lab capabilities of the students. It can be understood as a validation test and will consist in performing SPICE simulations, writing a short MATLAB and answering some multiple choice questions.

Contents module	Hours in classroom (or supervised lab)			Hours outside the classroom (and unsupervised lab)	
	LECTURE (medium group)	SEMINAR (medium group)	LAB (small group)		
M1	4	2	–	8	
M2	7	5	–	18	
M3	5	5	–	20	
M4	2	–	–	7	
M5	2	–	–	7	
M6	2	–	–	7	
M7	–	–	10	14	
Total	22	12	10	81	125

6. Assessment

Some common remarks:

- In case a student cannot attend a session in which a test is performed (AC1, AC2, AL1 and AL3), his or her grade for that test will be 0. Under no circumstances tests will be repeated for individual students.

- As a general rule, grades for lab activity AL2 will be the same for both lab team members. In case a student cannot attend the lab session in which this activity is assessed (AL2), his or her labmate will carry out the activity by himself or herself and, under the agreement of the present labmate, the non-attending student will get the same grade as assessed student.

- Punctuality will be strictly enforced. Particularly in lab sessions: nobody will be admitted in lab 20 minutes after the scheduled start time and grades will be penalized since 5 minutes after the scheduled start time.

- Grade revision dates for tests will be indicated in the Aula Global.

- **Very important: copies or plagiarism will not be tolerated at all!**

Assessed Competences	Assessment activity (and typology)	Assessment methodology and criteria	Minimum grade to pass the course	Recoverable (in July)	Weight on final grade
INS3, B1, B6, IB1, IB2	**AL1.** Lab introduction feedback test (Written Test)	Short multiple-choice test performed at the end of the second lab session.	0	No	5%
INS1, INS2, INS3, INT1, SIS1, SIS4, B1, B2, B6, P1, P5, IB1, IB2, O1, O2	**AL2.** Spirometry project demonstration (Execution test)	During the last session corresponding to this project, the professor will check the performance of the implemented system. The professor will assess it in terms of capability to perform the requested measurements and the accuracy of those measurements (35%), appearance and quality of the software interface (25%), correctness of the design and the implementation methodologies (25%) and originality and added difficulty of the implemented solutions (15%).	0	No	15%
INS1, INS3, INS7, SIS1, B1, B2, B6, P5, IB1, IB2, O1, O2	**AL3.** Lab test (Written and Execution tests)	At the last lab session, in addition to the assessment of the spirometry system, an execution test will be performed to individually asses the lab capabilities of the students. It can be understood as a validation test and will consist in performing SPICE simulations, writing a short MATLAB and answering some multiple-choice questions.	0	No	10%
INS1, INS3, INS7, B1, B6, P5, IB1, IB2, IB7	**AC1.** M1-M2 feedback test (Written Product)	Multiple-choice test plus one or two problems.	0	No	5%
INS1, INS3, INS7, B1, B6, P5, IB1, IB2, IB3, IB7	**AC2.** M3 feedback test (Written Product)	Multiple-choice test plus one or two problems.	0	No	10%
INS1, INS3, INS7, B1, B6, P5, IB1, IB2, IB3, IB7	**AF.** Final exam (Written Test)	Modules 1 to 6 will be assessed by multiple choice questions plus three to eight comprehensive problems to be solved.	5 over 10	Yes	55%

7. Schedule

week	First plenary slot Plenary lesson or seminar (T1 & P101)	Second plenary slot Plenary lesson or seminar (T1 & P101)	Laboratory slots Thursday or Friday (S101 and S102)
1 Sept 22 – Sept 26	(Thursday 10:30 – 12:30) Course presentation **(M0)** and **Lecture M1**	(Friday 8:30 – 10:30) **Lecture M1**	(no lab)
2 Sept 29 – Oct 03	(Monday 10:30 – 12:30) **Seminar M1**	(Thursday 8:30 – 10:30) **Lecture M2**	(no lab)
3 Oct 06 – Oct 10	(Monday 10:30 – 12:30) **Seminar + Lecture M2**	(Friday 10:30 – 12:30) **Lecture M2**	**S101. Lab 1** (Th 10:30 – 12:30) (S102. no lab)
4 Oct 13 – Oct 17	(no class)	(Thursday 10:30 – 12:30) **Lecture M2**	(S101. no lab) **S102. Lab 1** (Th 12:30 – 14:30)
5 Oct 20 – Oct 24	(Monday 10:30 – 12:30) **Seminar M2**	(no class)	**S101. Lab 2** (F 12:30 – 14:30) (S102. no lab)
6 Oct 27 – Oct 31	(Monday 8:30 – 10:30) **AC1. M1-M2 feedback test + Seminar M1-M2**	(Friday 10:30 – 12:30) **Lecture M3**	(S101. no lab) **S102. Lab 2** (F 12:30 – 14:30)
7 Nov 03 – Nov 07	(Monday 10:30 – 12:30) **Seminar + Lecture M3**	(Thursday 8:30 – 10:30) **Lecture M3**	**S101. Lab 3** (F 10:30 – 12:30) **S102. Lab 3** (Th 12:30 – 14:30)
8 Nov 10 – Nov 14	(Monday 8:30 – 10:30) **Seminar M3**	(no class)	**S101. Lab 4** (F 12:30 – 14:30) (S102. no lab)
9 Nov 17 – Nov 21	(Monday 10:30 – 12:30) **AC2. M3 feedback test + Seminar M3**	(Thursday 8:30 – 10:30) **Lecture M4**	(S101. no lab) **S102. Lab 4** (F 10:30 – 12:30)
10 Nov 24 – Nov 29	(Monday 10:30 – 12:30) **Lecture M5**	(no class)	**S101. Lab 5** (F 10:30 – 12:30) **S102. Lab 5** (F 12:30 – 14:30)
11 Dec 01 – Dec 06	(Monday 8:30 – 10:30) **Lecture M6**	(no class)	(no lab)
12-13 Dec 09 – Dec 20	**AF. Final exam** (data and hour to be determined)		

Notes:

- Extra *unsupervised lab sessions* are allocated between Lab 3 and Lab 5 (next page). In these *unsupervised lab sessions* – in which no professor will be present – the electronics lab 54.028 will be open for the students and the lab assistant, Genis Caminal, will be there for providing the materials and tools and to keep an a eye on materials and instruments.
- At the end of Lab 2 and Lab 5 sessions, assessment activities AL1 and AL2+AL3 respectively, will be carried out.

Extra unsupervised lab sessions

First extra lab session for group S101: 07/11/2014 from 13:30 to 16:30
First extra lab session for group S102: 06/11/2014 from 15:30 to 18:30

Second extra lab session for group S101: 20/11/2014 from 13:30 to 17:30
Second extra lab session for group S102: 21/11/2014 from 13:30 to 17:30

Third extra lab session for group S101: 24/11/2014 from 14:30 to 16:30
Third extra lab session for group S102: 24/11/2014 from 16:30 to 18:30

Assessment activities list

Activity	Relevant dates
AL1. Lab intro. test	Test on 24/10/2014 for group S101 Test on 31/10/2014 for group S102 Grades publication on 07/11/2014
AC1. Feedback test on M1-M2	Test on 27/10/2014 Grades publication on 4/11/2014
AC2. Feedback test on M3	Test on 17/11/2014 Grades publication on 28/11/2014
AL2. Spirometry project demonstration	Demonstration on 28/11/2014 for group S101 Demonstration on 28/11/2014 for group S102 Grades publication on 2/12/2014
AL3. Lab test	Test on 28/11/2014 for group S101 Test on 28/11/2014 for group S102 Grades publication on 5/12/2014
AF4. Final exam	(Exam date to be determined)

8. Bibliography and didactic resources

Suitable books available as free electronic resources at the web site of the UPF library (http://www.upf.edu/bibtic/):

1. "Biomedical Device Technology: Principles and Design", Anthony Y. K. Chan, publisher: Charles C Thomas Pub Ltd, 2008. ISBN 0398085773 (covers, in part: M1, M3, M4, M6).
2. "Medical Devices and Systems", (volume 3 of "The Biomedical Engineering Handbook"), 3rd edition, Joseph D. Bronzino (editor), publisher: CRC/Taylor & Francis, 2006. ISBN: 978-0-8493-2122-1 (covers in part: M1, M3, M4, M6).
3. "Linear Circuit Design Handbook", edited by Hank Zumbahlenas with the engineering staff of Analog Devices, publisher: Elsevier/Newnes Press, 2008. ISBN: 978-0750687034 (covers, in excessive detail: M3).
4. "Electrical circuit theory and technology", 2^{nd} edition, John Bird, publisher: Newnes, 2003. (covers: M2, M3, M5).
5. "Bioimpedance and bioelectricity basics", 2nd edition, Sverre J. Grimnes and Orjan G. Martinsen, Publisher: Academic Press, 2008, ISBN: 978-0123740045 (covers: M4, M6).

Additional suitable books available at the UPF library:

1. "Medical Instrumentation Application and Design", 4th edition, John G. Webster (editor), publisher: Wiley, 2009. ISBN: 978-0471676003 (covers: M1, M3, M4, M6).
2. "Introduction to Biomedical Equipment Technology", 4th edition, Joseph J. Carr and John M. Brown, publisher: Prentice Hall, 2000. ISBN: 978-0130104922 (covers: M1, M3, M4, M6).
3. "Introduction to Engineering Experimentation", 3rd Edition, Anthony J. Wheeler and Ahmad R. Ganji, publisher: Prentice Hall, 2009. 978-0131742765 (covers M1 in detail; good collection of problems)
4. "Principios de Electrónica" (Electronic Principles), Albert Paul Malvino, publisher: McGraw-Hill, 2007. ISBN: 978-8448156190 (covers: M2 and M3; extensive collection of problems).

Note: all these books focus on different specific topics covered by the course. Unfortunately, each one of these books either does not cover some topics of the course or goes much deeper into the topics than what required in the BIS course, or both. That is, none of them should be considered singly as the reference book for the course (i.e. textbook).