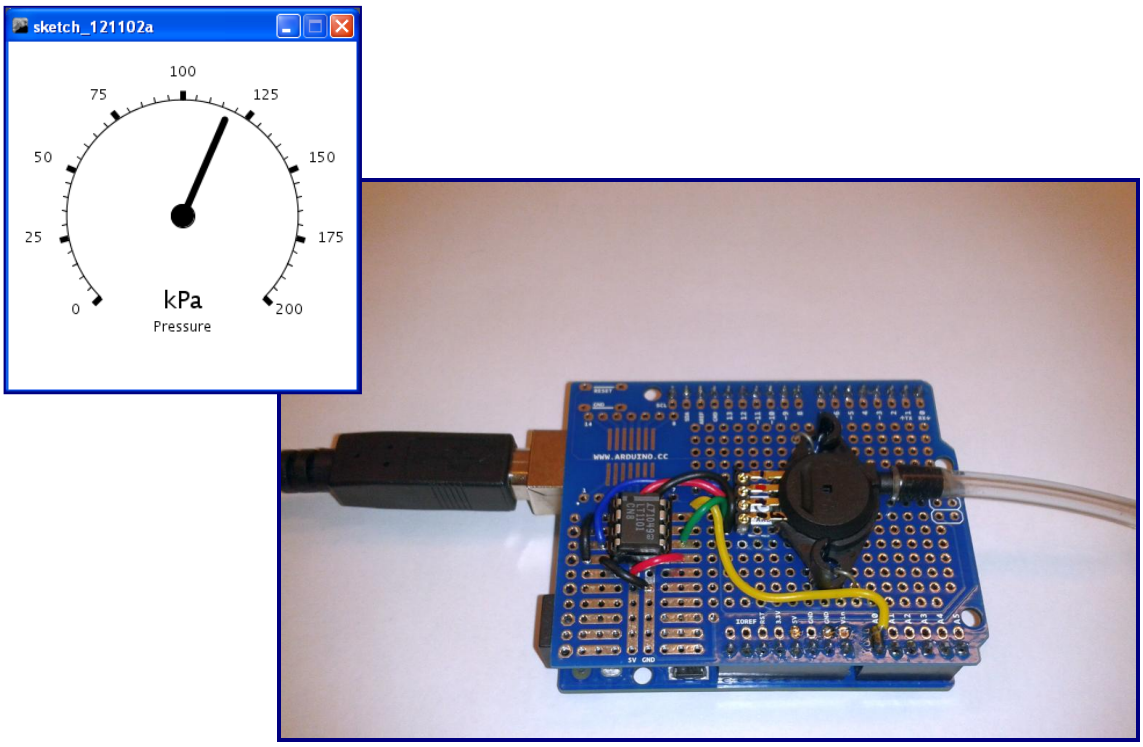

Teaching Plan

(version 1.0)

Course name: **Sensors and Data Acquisition** (Sensors i adquisició de dades)

Academic year: 2012-2013
Year: 3rd or 4th year (elective course)
Trimester: 2nd

Degrees: Bachelor's degree in Audiovisual Systems Engineering, Bachelor's degree in Telematics Engineering, Bachelor's degree in Computer Sciences

Course codes: 22645 (Audiovisual Systems Eng.), 22599 (Telematics Eng.), 22641 (Computer Sciences)

Number of ECTS credits: 4
Hours of student work: 100

Language in which the course is taught: English

Teachers: Antoni Ivorra
Responsible professor: Antoni Ivorra

1. Course descriptors

Course name: Sensors and Data Acquisition (Sensors i adquisició de dades)

Course acronym: SAD

Academic year: 2012-2013
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Degrees: Bachelor's degree in Audiovisual Systems Engineering, Bachelor's degree in Telematics Engineering, Bachelor's degree in Computer Sciences

Course codes: 22645 (Audiovisual Systems Eng.), 22599 (Telematics Eng.), 22641 (Computer Sciences)

Number of ECTS credits: 4
Hours of student work: 100

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
Lab assistant: Genís Caminal
Responsible professor: Antoni Ivorra

2. Course presentation

This elective course will deal with theoretical and practical aspects regarding the acquisition of numerical data and signals from nature by means of electronic sensors. The course aims three main teaching objectives: 1- to overview the fundamental features of measurement systems and the physical and electronic foundations of those systems, 2- to introduce the principles of design for electronic circuits capable of interfacing the electronic sensors to analog-to-digital converters and 3- to put in practice the above knowledge – and to get lab and hardware prototyping skills – by implementing electronic data acquisition systems.

It must be noted that this course emphasizes the relevance of hands-on lab work; both in grading and in effort the students will have to devote. In fact, an incidental goal of the course is to provide the students with practical knowledge and skills so that they are encouraged to carry out simple electronic hardware projects by themselves after the course. With this objective in mind, in the laboratory sessions it will be used one of the most popular microcontroller boards among electronic hobbyists: the Arduino Uno.

Short syllabus: General characteristics of measurement systems, circuit theory fundamentals, signal conditioning circuits, electronic sensors and their principles of action, analog-to-digital converters (ADCs) and sources of errors and interferences.

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) and 4- computer programming basics. In terms of courses at the Polytechnic School of the UPF: 1 and 2- "Ones i Electromagnetisme" or "Bioelectromagnetisme", 3- "Senyals i Sistemes" or "Teoria de Senyals i Sistemes" and 4- "Fonaments de la Programació" or "Tècniques Computacionals en Biomedicina".

3. Competences the course aims to teach or to train

Transversal competences	Specific competences
Instrumental **G1.** Ability for analysis and synthesis **G2.** Organization and planning ability **G3.** Ability for applying knowledge in practice **G4.** Information management skills **G5.** Decision making **G6 or G7.** Oral and written communication in academic or professional environments (in Catalan/Spanish or in English) **Interpersonal** **G8.** Teamwork **Systemic** **G11.** Ability for applying flexibly and creatively the acquired knowledge to new scenarios. **G14.** Concern for quality **G15.** Ability for generating new ideas	**Professional specific competences** **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** **B13.** Knowledge of circuit theory fundamentals and ability for analyzing and designing simple electronic circuits. **Other competences** **O1.** Ability for implementing simple electronic circuit prototypes based on discrete components. **O2.** Ability for performing circuit analysis using a SPICE simulator. **Specific competences in audiovisual engineering** **AU36.** Basic web design

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 - Uncertainty analysis (very brief overview)
Module 2 (**M2**)	**Overview of circuit theory fundamentals** - Ohm's law - Kirchhoff's circuit laws - Voltage dividers - Equivalent circuits - Ground loop - Diodes - Time transients in RC circuits - Impedance - Transfer function (frequency analysis) - Capacitively coupled noise - Inductively coupled noise - Simple passive filters
Module 3 (**M3**)	**Signal conditioning circuits** - Ideal operation amplifier (OA) - Inverting and non-inverting OA configurations - Common mode voltage and differential voltage - Output voltage saturation - Single supply OAs - Limitations of real OAs (offset voltage, bias currents, PSRR, CMRR, bandwidth, slew rate) - Differential amplifier configuration - Instrumentation amplifier - Wheatstone bridge - Isolation
Module 4 (**M4**)	**Analog-to-digital converters and digital sensors** - Quantification errors - Sample-and-hold - Voltage-to-frequency converters - Flash ADC - Integrating ADC - Successive approximation ADC - Multiplexors - Aliasing in the context of low frequency data acquisition - Digital sensors
Module 5 (**M5**) (to be self-taught by the students; under guidance)	**Electronic sensors and their principles of action** - Temperature sensors (thermocouples, thermistors, P-N junction sensors, optical temperature sensors) - Strain and force sensors (strain gauges, piezoelectric sensors) - Light sensors (photodiodes, phototransistors, photoresistors, CCDs) - Acoustic sensors (dynamic microphones, condenser microphones, electret microphones, MEMs microphones) - Position and displacement sensors (potentiometric sensors, mercury drop sensors, MEMs accelerometers, MEMs gyroscopes, LVDT and RVDT sensors, Hall effect sensors, magnetoresistive sensors, linear optical sensors, optical encoders, ultrasound distance measurement)

5. Methodology

This course emphasizes the relevance of hands-on lab work; both in grading and in effort the students will have to devote. Said that, it must be pointed out that the course also follows a more conventional course structure in which lectures and problem solving seminars are combined with short tests – for feedback purposes – and a final written exam. This conventional teaching structure is mainly, but not exclusively, intended to provide the fundamentals that the students will require in order to perform the lab projects and other similar future projects.

Lectures and problem solving seminars. Contents modules M1 to M4 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.

Self-learning. Contents module M5, which corresponds to topics that are to be learnt by heart, will be self-prepared and self-learnt by the students. The professor will only provide some guidelines about the topics to be learnt and the depth of required knowledge. The students will be responsible for gathering the information (e.g. from the recommended text books), for synthesizing it, for generating the learning materials and, finally, for learning it. Students will be encouraged to create groups for the preparation of the materials.

Guided lab sessions. The lab sessions are organized in three projects: 1) "Introduction to the lab: measurements with a photodiode versus human vision" (first two sessions), 2) "Pressure sensor project: implementation of a barometer/altimeter" (third and fourth guided sessions) and 3) free project based on sensors.

The first four lab sessions (of two hours each and corresponding to projects 1 and 2) will be guided, particularly the first two ones. 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 simulations will be detailed.

These four 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) and during the execution of the fourth lab session (AL2).

No report will be required for any of the four guided lab sessions.

Autonomous lab sessions (free project). A short set of project proposals will be presented as examples of projects that the students will be able to perform (e.g. a pulse rate meter based on photoplethysmography, a 3D pointing device based on accelerometers, a simple weather station…). However, lab teams will be encouraged to develop their own original proposals. Those proposals will be checked by the professor for feasibility in terms of complexity, technical limitations, availability of materials and equipment...

All the necessary electronic components, materials and tools will be provided by the lab assistant with some obvious limitations regarding the range and quantity of available elements. In the exceptional case that the students require further materials for

developing their projects, they will have to acquire them by themselves with their own money. A cap of 25 Euros per lab team (demonstrable with purchase tickets) will be imposed so that all of them can compete equally (a fraction of the grade will depend on ranking according to students votes)

It will be requested that all these projects are based on the Arduino microcontroller platform. Students will familiarize with the Arduino platform during the third and fourth guided sessions. As a matter of fact, an unsupervised lab session has been allocated before these two lab sessions so that the students can familiarize by themselves with the Arduino boards and software by means of examples and tutorials.

Project development will be loosely supervised by the professor. It is expected that most of the development will be performed during unsupervised lab sessions and outside of the lab (students will be allowed to take home the materials).

Oral and web presentation of free project.

Each student team will give a short oral presentation (10 minutes) supported with PowerPoint slides on the developed free project. The professor will assess it in terms of preparation, organization, structure, balance and timing. Presentations given in English will be positively graded.

In addition, each student team will create a simple web site presenting their free project (for instance, created in Google Sites). The professor will assess it in terms of quality and richness of the presentation, achieved results in relation to the complexity of the project, correctness of the methodology and originality. In a secret ballot (through Aula Global) the students will rank all the projects and this ranking will provide the remaining percentage of grade for this activity. Web sites in English will be positively graded.

Contents module	Hours in classroom (or supervised lab)			Hours outside the classroom (and unsupervised lab)	
	Large group	Medium group	Small group		
M1	2.5	0	0	4	
M2	3.5	0	4	10	
M3	7	0	8	30	
M4	6	0	0	10	
M5	1	0	0	20	
Total	20	0	12	68	100

6. Assessment

Some common remarks:

- Deadlines for deliverables will be strictly enforced. Three points (over 10) will be subtracted from the corresponding activity grade per day of delay (integer “ceil” counting from minute 1 after scheduled time deadline).

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

- Grades for lab activities AL2, AL3 and AL4 will be the same for both lab team members. In case a student cannot attend a lab session in which those activities are assessed, 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.

- The student is responsible for keeping electronic copies of all deliverables.

- Grade revision dates for tests and deliverables 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
B13	**AL1.** Lab introduction feedback test (Written Test)	Short multiple-choice test performed at the end of the second lab session.	0	No	2.5%
G3, G8, G14, B13, O1, O2	**AL2.** Pressure sensor project (Execution test)	During the second session corresponding to this project the professor will check the progress of the students.	0	No	7.5%
G1, B13	**AC1.** M1-M3 feedback test (Written Product)	Multiple-choice test plus one or two problems.	0	No	5%
G1, G2, G4	**AC2.** M5 feedback test (Written Product)	Short multiple-choice test on the self-taught module M5.	0	No	5%
G6(or G7), G8, G14, P1, P5, B13	**AL3.** Lab free project oral presentation (Execution Test)	Each student team will give a short oral presentation supported with PowerPoint slides on the developed free project. The professor will assess it in terms of preparation, organization, structure, balance and timing. Presentations given in English will be positively graded (+25% of the grade for this activity).	0	No	10%
G3, G5, G6 (or G7), G8, G11, G14, G15, P1, P5, B13, O1, O2,AU36	**AL4.** Lab free project web (Written Test)	Each student team will create a web site presenting their free project. The professor will assess it in terms of quality and richness of the presentation (25%), achieved results in relation to the complexity of the project (25%), correctness of the methodology (25%) and originality (10%). In a secret ballot (through *Aula Global*) the students will rank all the projects and this ranking will provide the remaining 15% of grade for this activity (10 over 10 for the project highest rank and 0 for the project with the lowest rank) Web sites in English will be positively graded (+25% of the grade for this activity).	5 over 10	No	30%
G1, G2, G4, B13	**AF.** Final exam (Written Test)	Modules 1 to 4 will be assessed by multiple choice questions plus two to four comprehensive problems to be solved. Module 5 will be assessed by a multiple choice test and its relative weight on the final exam grade will be 20%	5 over 10	Yes	40%

7. Schedule

week	Monday 14:30-16:30 Plenary lesson or seminar (T1 & P101)	Tuesday 18:30-20:30 Lab group 1 (S101)	Friday 16:30-18:30 Lab group 2 (S102)
1 Jan 7- Jan 11	Course presentation and intro. to measurement systems (M1)	(no class)	(no class)
2 Jan 14 – Jan 18	**Lecture** on Circuit Theory Fundamentals (M2)	**Lab session 1**: Intro. to lab and photodiode project (1/2)	**Lab session 1**: Intro. to lab and photodiode project (1/2)
3 Jan 21 – Jan 25	1st **Lecture** on Signal Conditioning Circuits (M3)	**Lab session 2**: Intro. to lab and photodiode project (2/2) **AL1.** Lab intro. test	**Lab session 2**: Intro. to lab and photodiode project (2/2) **AL1.** Lab intro. test
4 Jan 28 – Feb 1	2nd **Lecture** on Signal Conditioning Circuits (M3)	Unsupervised lab session: Introduction to Arduino	Unsupervised lab session: Introduction to Arduino
5 Feb 4- Feb 8	**Seminar** (problem solving) on M2 and M3	**Lab session 3**: Pressure sensor project (1/2)	**Lab session 3**: Pressure sensor project (1/2)
6 Feb 11- Feb 15	**AC1.** Test on M1-M3 3rd **Lecture** on SCEs (M3)	**Lab session 4**: Pressure sensor project (2/2) **AL2.** Execution assessed	**Lab session 4**: Pressure sensor project (2/2) **AL2.** Execution assessed
7 Feb 18- Feb 22	1st **Lecture** on ADCs (M4)	**Lab session 5**: Free project	**Lab session 5**: Free project
8 Feb 25 – Mar 1	2nd **Lecture** on ADCs (M4)	Unsupervised lab session: Free project	Unsupervised lab session: Free project
9 Mar 4- Mar 8	**AC2.** Test on M5 3rd **Lecture** on ADCs (M4)	Unsupervised lab session: Free project	Unsupervised lab session: Free project
10 Mar 11- Mar 15	**Seminar** (problem solving) on M2, M3 and M4	**Lab session 6**: Free project **AL3.** Project presentation	**Lab session 6**: Free project **AL3.** Project presentation
11-12 Mar 18- Apr 5	**AL4.** Free project web. Publication of web site for the project (4 days after oral presentation) **AF.** Final exam (data and hour to be determined)		

In the *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.

Note that in the official ESUP schedule ("Horaris") for the second trimester slots for lectures and seminars are indicated as "TEORIA" and slots for supervised lab sessions are indicated as "SEMINARI" and slots for unsupervised lab sessions as "PRÀCTIQUES".

Activities list

Activity	Relevant dates
AL1. Lab intro. test	Test on March 22 for group S101 Test on March 25 for group S102 Grades publication on February 4
AL2. Sensor project assessment	Execution assessed on February 12 for group S101 Execution assessed on February 15 for group S102 Grades publication on February 18
AC1. Feedback test on M1-M3	Test on February 11 Grades publication on February 25
AC2. Feedback test on M5	Publication of M5 self-teaching guidelines on January 18 Test on March 5 Grades publication on March 15
AL3. Free project oral presentation	Presentation on March 12 for group S101 Presentation on March 15 for group S102
AL4. Free project web publication (and voting)	Web publication deadline March 21 for both groups Ballot publication March 23 Voting deadline March 25 (*) Grades publication on March 27
AF4. Final exam	(Exam date to be determined)

* Vote is mandatory; any student who does not vote will not get his or her grade corresponding to the popular ranking (i.e. 15% of the activity grade)

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. “Handbook of modern sensors: physics, designs, and applications”, Third edition, Jacob Fraden, publisher: Springer-Verlag, 2004. ISBN 0-387-00750-4
2. “Measurement and instrumentation: theory and application”, Alan S. Morris and Reza Langar, publisher: Academic Press, 2012. ISBN 978-0-12-381960-4
3. “Linear circuit design handbook”, edited by Hank Zumbahlenas with the engineering staff of Analog Devices, publisher: Elsevier/Newnes Press, 2008. ISBN: 978-0750687034.

Additional suitable books:

1. “Sensors and Signal Conditioning”, 2nd Edition, Ramón Pallás-Areny and John G. Webster, publisher: Wiley-Interscience, 2000. ISBN: 978-0471332329
2. “Introduction to Engineering Experimentation”, 3rd Edition, Anthony J. Wheeler and Ahmad R. Ganji, publisher: Prentice Hall, 2009. 978-0131742765

Note: all these books focus on different specific topics covered by the course and they go much deeper into those topics than what will be required in the SAD course. That is, none of them should be considered as the reference book for the course. Nevertheless, the first one (Handbook of modern sensors: physics, designs, and applications) may be considered as the closest one to the ideal reference book for the SAD course.