295127 - 29511011 - Data Acquisition & Instrumentation

Coordinating unit:  295 - EEBE - Barcelona East School of Engineering
Teaching unit:  710 - EEL - Department of Electronic Engineering
Academic year:  2019
Degree:  MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019).
(Teaching unit Compulsory)
ECTS credits:  6
Teaching languages:  Spanish, English

Teaching staff
Coordinator:  Martinez Garcia, Herminio
Others:  Martinez Garcia, Herminio
Cosp Vilella, Jordi

Opening hours
Timetable:  It will be published during the first week of the course.

Prior skills
A course on basic electronics or fundamental of electronics such as “Electronics Systems” (STI – 820017), taught at the EEBE.

Requirements
A course on basic electronics or fundamental of electronics such as “Electronics Systems” (STI – 820017), taught at the EEBE.

Degree competences to which the subject contributes

Specific:
CEMUEII-01. Apply sensing, instrumentation and data acquisition technologies for the characterization, monitoring and control of the state of a system, plant or process.

Generic:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.

Transversal:
05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
06 URI. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
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Teaching methodology

- Master classes: 60%.
- Lab sessions: 30%.
- Conferences and workshops: 10%.

Learning objectives of the subject

Following successful completion of the course, students should be able to:

1. Describe the elements in a measurement system and their function.
2. Describe sensor principles for electric and non-electric measurements.
3. Explain the principles of operation of the main types of sensors.
4. Utilize the merits of various types of sensors for a wide range of applications.
5. Understand the limitations in the performance of instrumentation systems.
6. Analyze the specifications of various types of sensors and understand the main characteristics of sensors.
7. Implement instrumentation systems.
8. Select appropriate sensors for a given application and design simple electronic sensor interface systems.
9. Select components for instrumentation systems.
10. Present possible coupling mechanisms between noise sources and the measurement circuit, and how the uncertainty in a measurement can be estimated and presented.

The course consists of a set of lectures to introduce sensors and advanced electronics systems in the framework of measurements, data acquisition systems and instrumentation technologies. As a consequence, some lab sessions and personal work supervised by faculty to develop a project. The course will be PBL oriented. In particular, the course will be PBL oriented in order to design, simulate and implement a data acquisition systems (DAS) devoted to sense a set of environment or meteorological variables.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group:</th>
<th>34h</th>
<th>22.67%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours medium group:</td>
<td>0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Hours small group:</td>
<td>20h</td>
<td>13.33%</td>
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<tr>
<td></td>
<td>Guided activities:</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Self study:</td>
<td>96h</td>
<td>64.00%</td>
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</tbody>
</table>
### Input Signal Conditioning: Low Power Amplification and Analog Processing.

**Description:**
- General concepts and terminology in data acquisition systems (SAD).
- General structure of a measurement and control system.
- Review of signal amplification.
- Differential amplifier (DA) and instrumentation amplifiers (IA).
  - CMRR (common mode rejection ratio) and PSRR (power supply rejection ratio) errors.
  - Examples of application.
- Isolation amplifiers (AA).
  - IMRR (isolation mode rejection ratio) errors.
  - Examples of application.
- Static limitations in integrated amplifiers.
  - Input offset voltage. Low offset voltage VFOAs.
  - Offset currents and bias currents. Low bias current VFOAs.
  - Compensation techniques for offset errors in VFOAs.
  - Effect of the offset voltage, and bias and offset currents on the behavior of the circuit.
  - Temperature effects on static limitations.
- Dynamic limitations.
  - VFOA’s open loop gain.
  - VFOA’s open and closed loop gain responses. Gain-bandwidth product.
  - Input and output impedances.
  - Transient response. Slew-rate limitations.
  - Full power bandwidth (FPB).
  - VFOA’s frequency response on the behavior of a circuit.
  - Temperature effects on dynamic limitations.
- Linearization circuits.
  - The reason of linearization.
  - Linearization based on logarithmic and exponential amplifiers.
  - Linearization based on analog multipliers.
- Linear signal filtering.
  - Design process based on first and second order RC active filtering cells.
- Analog switches and multiplexers.
- Application to the PGDA (programmable gain differential amplifier).
- Data registration and dataloggers.
- Data logging versus data acquisition.
- Communication protocols.
- Specifications
- Applications.
- Examples.

**Related activities:**
- Lectures on input signal conditioning.
- Laboratory sessions (Activity 1): Simulation of input signal conditioning circuits.
- Laboratory sessions (Activity 2): Static and dynamic limitations in integrated amplifiers.

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**Learning time:** 31h
- Theory classes: 7h
- Laboratory classes: 4h
- Self study: 20h
**Specific objectives:**
Study the analog front-end in data acquisition systems, especially their DC and AC errors in order to obtain optimal designs.

<table>
<thead>
<tr>
<th>Capture of the Measurement Signal: Sensors.</th>
<th>Learning time: 17h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>• Classification of sensors.</td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td>• Linear and non-linear sensors.</td>
<td>Self study: 11h</td>
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<tr>
<td>• Analog and digital sensors.</td>
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<tr>
<td>• Modulator and generator sensors.</td>
<td></td>
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<tr>
<td>• Voltage divider for the acquisition of measurements.</td>
<td></td>
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<tr>
<td>• Wheatstone bridge for acquisition of measurements.</td>
<td></td>
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<tr>
<td>• Alternatives to the Wheatstone bridge: Pseudo-bridges.</td>
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</tr>
</tbody>
</table>

**Related activities:**
• Lectures on sensing elements and devices.
• Laboratory sessions (Activity 3): Implementation of input signal conditioning stages for a particular sensing element.
<table>
<thead>
<tr>
<th>Output Signal Conditioning: Actuators and Final Control.</th>
<th>Learning time: 31h</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Electronics associated with electromechanical actuators.</td>
<td>Theory classes: 7h</td>
</tr>
<tr>
<td>- Opto-isolation of input and output signals.</td>
<td>Laboratory classes: 4h</td>
</tr>
<tr>
<td>• Power amplifiers.</td>
<td>Self study: 20h</td>
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<tr>
<td>- Darlington stages and complementary-symmetry push–pull amplifiers.</td>
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<tr>
<td>- Operational power amplifiers.</td>
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<tr>
<td>- Commercial ICs for power amplifiers and low frequency amplifiers.</td>
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<tr>
<td>• Stages with thyristors (SCR) and TRIACs.</td>
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<tr>
<td>- Control of activation. Activation with DIACs.</td>
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<tr>
<td>• Industrial automatic controllers.</td>
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<tr>
<td>- Discontinuous and continuous controllers.</td>
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<tr>
<td>- Tuning of electronic controllers.</td>
<td></td>
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<tr>
<td>• Analog and digital implementation of electronic controllers.</td>
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</tr>
<tr>
<td>- Discretization of analog signals and control laws.</td>
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<tr>
<td>- Analog controllers and their discretization.</td>
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<tr>
<td>- Digital implementation.</td>
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<tr>
<td>• Introduction to digital filters and digital signal processors (DSPs).</td>
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</tbody>
</table>

**Description:**

- Lectures on output signal conditioning.
- Laboratory sessions (Activity 4): Simulation of output signal conditioning circuits.
- Laboratory sessions (Activity 5): Implementation of an analog subsystem for a complete data acquisition system.

**Specific objectives:**

- Electronics associated with electromechanical actuators.
- Opto-isolation of input and output signals.
- Power amplifiers.
  - Darlington stages and complementary-symmetry push–pull amplifiers.
  - Operational power amplifiers.
  - Commercial ICs for power amplifiers and low frequency amplifiers.
- Stages with thyristors (SCR) and TRIACs.
  - Control of activation. Activation with DIACs.
- Industrial automatic controllers.
  - Discontinuous and continuous controllers.
  - Tuning of electronic controllers.
- Analog and digital implementation of electronic controllers.
  - Discretization of analog signals and control laws.
  - Analog controllers and their discretization.
  - Digital implementation.
- Introduction to digital filters and digital signal processors (DSPs).

**Learning time:**

- Theory classes: 7h
- Laboratory classes: 4h
- Self study: 20h
# Microcontroller-Based Systems

**Learning time:** 44h  
Theory classes: 10h  
Laboratory classes: 6h  
Self study: 28h

**Description:**  
- Microcontroller basics.  
- Components of a microcontroller system.  
- Communications.  
- Programming the microcontroller.  
- Interfacing sensors and actuators.

**Related activities:**  
- Lectures on microcontroller systems.  
- Laboratory session (Activity 6): Introduction to a microcontroller development platform.  
- Laboratory session (Activities 7 and 8): Programming the microcontroller.

**Specific objectives:**  
- Understand microcontroller principles and develop the necessary abilities to develop systems based on microcontrollers.

# Analog-to-Digital (ADC) and Digital-to-Analog (DAC) Conversion

**Learning time:** 27h  
Theory classes: 6h  
Laboratory classes: 4h  
Self study: 17h

**Description:**  
- Sampling.  
- Sample & Hold.  
- Quantization.  
- Accuracy.  
- Digital-to-Analog conversion.  
- Nyquist ADC’s.  
- Sigma-Delta ADC.  
- Digital-to-Analog conversion.

**Related activities:**  
- Lectures on ADC and DAC conversion.  
- Laboratory sessions (Activities 9 and 10): ADC conversion.

**Specific objectives:**  
- Understand ADC and DAC principles and develop the necessary abilities to use them in a microcontroller system.
Qualification system

- Midterm exam: 30%
- Final exam: 30%
- Lab sessions and activities: 20%.
- Guided activities: 20%.

Since it is a course with continuous (ongoing) assessment, there is not final re-assessment test.

Regulations for carrying out activities

It will be published during the first week of the course.

Bibliography

Basic:


Chesmond, Colin J. Basic control system technology. London [etc.]: Edward Arnold, 1990. ISBN 034050143X.


Complementary:


