Course guide
270070 - PDS - Digital Signal Processing

Unit in charge: Barcelona School of Informatics
Teaching unit: 707 - ESAII - Department of Automatic Control.
Degree: BACHELOR’S DEGREE IN INFORMATICS ENGINEERING (Syllabus 2010). (Optional subject).
Academic year: 2022  ECTS Credits: 6.0  Languages: Catalan

LECTURER
Coordinating lecturer: ANTONI GRAU SALDES
Others: Primer quadrimestre:
        ANTONI GRAU SALDES - 10

PRIOR SKILLS
Programming in language C.
To know how numbers are represented on a computer, and know how to perform arithmetic-logical operations.
To know the operation and structure of the processor.
To know the architecture and operation of a computer.
To understand written documentation in English correctly.

REQUIREMENTS
- Prerequisite CI
DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEC1.1. To design a system based on microprocessor/microcontroller.
CEC1.2. To design/configure an integrated circuit using the adequate software tools.
CEC2.3. To develop and analyse software for systems based on microprocessors and its interfaces with users and other devices.
CEC3.1. To analyse, evaluate and select the most adequate hardware and software platform to support embedded and real-time applications.
CEC3.2. To develop specific processors and embedded systems; to develop and optimize the software of these systems.
CT1.1B. To demonstrate knowledge and comprehension about the fundamentals of computer usage and programming. Knowledge about the structure, operation and interconnection of computer systems, and about the fundamentals of its programming.
CT1.2A. To interpret, select and value concepts, theories, uses and technological developments related to computer science and its application derived from the needed fundamentals of mathematics, statistics and physics. Capacity to solve the mathematical problems presented in engineering. Talent to apply the knowledge about: algebra, differential and integral calculus and numeric methods; statistics and optimization.
CT1.2B. To interpret, select and value concepts, theories, uses and technological developments related to computer science and its application derived from the needed fundamentals of mathematics, statistics and physics. Capacity to understand and dominate the physical and technological fundamentals of computer science: electromagnetism, waves, circuit theory, electronics and photonics and its application to solve engineering problems.
CT1.2C. To use properly theories, procedures and tools in the professional development of the informatics engineering in all its fields (specification, design, implementation, deployment and products evaluation) demonstrating the comprehension of the adopted compromises in the design decisions.
CT2.3. To design, develop, select and evaluate computer applications, systems and services and, at the same time, ensure its reliability, security and quality in function of ethical principles and the current legislation and normative.
CT5.5. To use the tools of a software development environment to create and develop applications.
CT5.6. To demonstrate knowledge and capacity to apply the fundamental principles and basic techniques of parallel, concurrent, distributed and real-time programming.
CT6.2. To demonstrate knowledge, comprehension and capacity to evaluate the structure and architecture of computers, and the basic components that compound them.
CT7.2. To evaluate hardware/software systems in function of a determined criteria of quality.

Generical:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

TEACHING METHODOLOGY

No distinction will be made between theory classes and problems, the theoretical classes will be reinforced with examples showing possible alternatives and solutions to problems in the field of DSP (both components of a DSP system and applications). The lab sessions will be held ‘in situ’ in the teaching laboratory of the department at the FIB. It is an unavoidable requirement to have carried out a previous work that will be specified by each one of the practices.
LEARNING OBJECTIVES OF THE SUBJECT

1. Differentiate the different types of systems, and define their characteristics
2. Understand the specific characteristics of a DSP processor over a general purpose processor
3. Differentiate the different types of signals, and define their characteristics
4. Understand the meaning and benefits of digital signal processing (PDS), and what are the most common areas of application
5. Understand the basics of the analog-to-digital conversion process, the interface needed in a DSP system, and the inherent limitations of this process.
6. Specify, analyze, and determine the basic parameters of an analog input or output interface (acquisition and reconstruction).
7. Know and apply the duality of the time-frequency domain of the signal. Understand the relationships between the two domains
8. Master the various alternatives for the implementation of the Fourier transform by discrete signals
9. Recognize the usefulness of discrete transformations in the field of PDS, and know how to apply these techniques
10. Use the z-transform for the representation, analysis and design of signals and discrete systems
11. Define the most common applications of the z transform in PDS systems
12. Know and be able to apply the correlation technique in the field of PDS
13. Know the areas of application of filters in DSP systems
14. Design filters according to the requirements of the application
15. Know how to apply FIR filters and IIR filters according to the requirements of the application
16. Know the differences in the architecture of floating point and fixed point DSPs
17. Analyze the errors inherent in the systems DSP due to quantification and finite resolution
18. Know how to use DSP-based development environments for rapid prototype development
19. Know how to use numerical computing packages for simulation, analysis and development of algorithms in the field of DSP
20. Know how to apply DSP techniques in audio systems
21. Know how to apply DSP techniques in the field of imaging
22. Know how to use DSP techniques in the field of video
23. Apply information compression techniques (JPEG, MPEG, ...)
24. Know the basic components of a digital signal processing system
25. Know and be able to apply the convolution technique in the field of PDS

STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study</td>
<td>84,0</td>
<td>56.00</td>
</tr>
<tr>
<td>Hours large group</td>
<td>18,0</td>
<td>12.00</td>
</tr>
<tr>
<td>Hours small group</td>
<td>30,0</td>
<td>20.00</td>
</tr>
<tr>
<td>Hours medium group</td>
<td>12,0</td>
<td>8.00</td>
</tr>
<tr>
<td>Guided activities</td>
<td>6,0</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Total learning time: 150 h

CONTENTS

Introduction

Description:
- Senyals, sistemes i processat del senyal.
- Aplicacions del PDS
- Operadors bàsics en el PDS
- Arquitectura dels microprocessadors DSP
- Estructura dels sistemes PDS
### Signal discretization

**Description:**
- Mostreig de senyals. Sinusoide mostrejada.
- Teorema del mostreig.
- Espectre dels senyals mostrejats.
- Relació de freqüències continu-discret.
- Conversió analògic a digital. Quantificacions.
- Conversió digital a analògic. Reconstrucció.

### Fourier Transform

**Description:**
- Applications. Equalization, filtering and audio, image and video compression.
- Discrete Fourier Transform (DFT).
- Fast Fourier Transform (FFT).
- Inverse Fourier Transform

### Z-transform and signal processing

**Description:**
- Transformada Z.
- Transformada Inversa Z.
- Propietats de la transformada Z.
- Aplicacions de la transformada Z en el PDS

### Correlation and convolution

**Description:**
- Correlació creuada i autocorrelació
- Fast correlation.
- Exemples d’aplicacions.

### Digital Filters

**Description:**
- Introducció
- Funció de transferència.
- Resposta impulsional.
- Estabilitat.
- Resposta freqüencial.
- Estructures.
- Criteris i procediment pel disseny de filtres digitals
- Disseny de filtres de resposta impulsional finita
- Disseny de filtres de resposta impulsional infinita
- Exemples
Processors for signal processing

Description:
- Arquitectura i tipus
- Criteris de selecció.
- Implementació dels algorismes en PDS de propòsit general.
- PDS de propòsit específic.
- Sistemes de desenvolupament pel PDS.

Audio signal processing

Description:
Equalització
Efectes de so
Compressió
Sintetitzador de so i veu

Image and video signal processing

Description:
Formats d'imatges. Compressió
Efectes d'imatge
Equalització
Compressió de vídeo

ACTIVITIES

DSP teamwork (IIII)

Specific objectives:
4, 7, 8, 11, 12, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 8h
Guided activities: 2h
Self study: 6h
DSP teamwork (I)

Specific objectives:
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 24, 26

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 12h
Guided activities: 2h
Self study: 10h

DSP teamwork (II)

Specific objectives:
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 18h
Guided activities: 2h
Self study: 16h

Development of Topic 1

Description:
Participate actively in the face-to-face session. Autonomous study of the proposed materials. Solving the proposed problems. Search for information and systems in which PDS is key.

Specific objectives:
4, 24

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 5h
Theory classes: 1h 30m
Practical classes: 0h 30m
Self study: 3h
(ENG) Desenvolupament del Tema 2

Description:
(ENG) Participar activament en la sessió presencial. Estudi autònom dels materials propossats. Resolució dels problemes proposats.

Specific objectives:
(ENG) 1, 3, 5, 6

Material:
(ENG)

Delivery:
(ENG)

Related competencies :
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 4h
Theory classes: 1h 24m
Practical classes: 0h 36m
Self study: 2h

(ENG) Desenvolupament Tema 3

Description:
(ENG) Participar activament en les sessions presencials. Estudi autònom dels materials proposats. Resolució dels problemes proposats. Recerca d'informació respecte les diferents transformades discretes: concepte, propietats, implementació i aplicació en el PDS.

Specific objectives:
(ENG) 4, 7, 8, 9, 20, 21, 22

Material:
(ENG)

Delivery:
(ENG)

Related competencies :
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 9h
Theory classes: 3h
Practical classes: 1h
Guided activities: 1h
Self study: 4h
**Desenvolupament Tema 4**

**Description:**
(ENG) Participar activament en les sessió presencial. Estudi autònom dels materials proposats. Resolució dels problemes proposats

**Specific objectives:**
(ENG) 10, 11

**Material:**
(ENG)

**Delivery:**
(ENG)

**Full-or-part-time:** 4h
Theory classes: 1h 24m
Practical classes: 0h 36m
Self study: 2h

**Desenvolupament Tema 5**

**Description:**
(ENG) Participar activament en la sessió presencial. Estudi autònom dels materials proposats. Resolució dels problemes proposats

**Specific objectives:**
(ENG) 12, 26

**Material:**
(ENG)

**Delivery:**
(ENG)

**Full-or-part-time:** 4h
Theory classes: 1h 24m
Practical classes: 0h 36m
Self study: 2h
(ENG) Desenvolupament Tema 6

Description:
(ENG) Participar activament en les sessions presencials. Estudi autònom dels materials proposats. Resolució dels problemes proposats

Specific objectives:
(ENG) 7, 13, 14, 15

Material:
(ENG)

Delivery:
(ENG)

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 8h
Theory classes: 2h 30m
Practical classes: 1h 30m
Self study: 4h

(ENG) Desenvolupament Tema 7

Description:
(ENG) Participar activament en les sessions presencials. Estudi autònom dels materials proposats. Resolució dels problemes proposats

Specific objectives:
(ENG) 2, 4, 16, 17, 18, 20, 21, 24

Material:
(ENG)

Delivery:
(ENG)

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 7h
Theory classes: 2h
Practical classes: 2h
Self study: 3h
(ENG) Desenvolupament Tema 8

Description:
(ENG) Participar activament en les sessions presencials. Estudí autònom dels materials proposats. Resolució dels problemes proposats

Specific objectives:
(ENG) 4, 17, 18, 19, 20, 23, 24

Material:
(ENG)

Delivery:
(ENG)

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 8h
Theory classes: 2h
Practical classes: 2h
Guided activities: 1h
Self study: 3h

(ENG) Desenvolupament Tema 9

Description:
(ENG) Participar activament en les sessions presencials. Estudí autònom dels materials proposats. Resolució dels problemes proposats

Specific objectives:
(ENG) 4, 17, 18, 19, 21, 22, 23

Material:
(ENG)

Delivery:
(ENG)

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 9h
Theory classes: 2h
Practical classes: 2h
Guided activities: 1h
Self study: 4h
(ENG) Pràctica 1

Description:
(ENG) Lectura comprensiva de l'enunciat de la pràctica, i de la resta de materials indicats a l'enunciat.
Realització de les activitats prèvies indicades a l'enunciat.
Realització dels exercicis que s'han d'entregar a l'inici de la sessió de laboratori.

Specific objectives:
(ENG) 1, 2, 3, 4, 5, 6, 17, 18, 20, 24

Material:
(ENG)

Delivery:
(ENG)

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 10h
Laboratory classes: 6h
Self study: 4h

(ENG) Pràctica 2

Description:
(ENG) Lectura comprensiva de l'enunciat de la pràctica, i de la resta de materials indicats a l'enunciat.
Realització de les activitats prèvies indicades a l'enunciat.
Realització dels exercicis que s'han d'entregar a l'inici de la sessió de laboratori.

Specific objectives:
(ENG) 2, 4, 7, 8, 9, 10, 11, 12, 20, 24, 26

Material:
(ENG)

Delivery:
(ENG)

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 12h
Laboratory classes: 6h
Self study: 6h
(ENG) Pràctica 3

Description:
(ENG) Lectura comprensiva de l’enunciat de la pràctica, i de la resta de materials indicats a l’enunciat. Realització de les activitats prèvies indicades a l’enunciat.

Specific objectives:
(ENG) 1, 2, 3, 4, 13, 14, 15, 19

Material:
(ENG)

Delivery:
(ENG)

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 8h
Laboratory classes: 4h
Self study: 4h

(ENG) Pràctica 4

Description:
(ENG) Lectura comprensiva de l’enunciat de la pràctica, i de la resta de materials indicats a l’enunciat. Realització de les activitats prèvies indicades a l’enunciat.

Specific objectives:
(ENG) 16, 17, 18, 19, 20, 23

Material:
(ENG)

Delivery:
(ENG)

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 10h
Laboratory classes: 4h
Self study: 6h
Práctica 5

Description:
(ENG) Lectura comprensiva de l'enunciat de la pràctica, i de la resta de materials indicats a l'enunciat. Realització de les activitats prèvies indicades a l'enunciat.

Specific objectives:
(ENG) 17, 19, 21, 22, 23

Material:
(ENG)

Delivery:
(ENG)

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

Full-or-part-time: 14h
Laboratory classes: 6h
Self study: 8h

Specific objectives:
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26

Related competencies:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.

GRADING SYSTEM

The grade of the subject is obtained from two components: the teamwork project (NT) and the laboratory grade (NL). Both components weigh 50% of the final grade.

NT is obtained from a teamwork project which has a weight of 90% in the NT, and the evaluation of activities directly related to transversal competence (ACT), which has a weight of 10% in the NT.

ACT is obtained from the realization of a work related to the content of the subject, where the student will look for information to complete the aspects worked. Special attention is paid to the quality of the references used, their obtaining and critical assessment, and their correct citation.

The NL laboratory mark is obtained from the average of the individual evaluations of the practices. There will be 5 evaluable practices during the course.

BIBLIOGRAPHY

Basic:

Complementary:
- Texas Instrument. C5515 eZDSP USB stick development tool.