Program	59EC – Communications Electronic Engineering B. Eng. 59SC – Telecommunications Systems Engineering B. Eng. 59SO – Sound and Image Engineering B.Eng. 59TL – Telematics Engineering B. Eng.

Course number and name	
Number	595000025, 595000324, 595000124, 595000224
Name	Digital Signal Processing
Semester	S4 [(February-June)]

Credits and contact hours	
ECTS Credits	4,5
Contact hours	45

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Specific course information

Description of course content

Some of the main deterministic digital signal processing techniques are introduced so this course could be a continuation of "Signals and Systems" and a detailing in discrete time signals and systems. There are three parts:

1) Sampling and digital processing of continuous signals. This topic shows the block diagram used to sample a continuous signal for processing on a digital microprocessor, it is reviewed the sampling theorem, discussed how to design a discrete system to be equivalent to a continuous system (and vice versa); the quantization noise that appears in real continuous-discrete converters is analyzed; finally there is an introduction to multirate processing (that is, changing the sample rate within the digital domain).
2) Discrete Fourier Transform (DFT). This topic presents one of the main tools currently used in signal processing systems: the discrete Fourier transform (DFT). The DFT allows calculating the Fourier transform of a discrete sequence in a microprocessor easily and quickly (through its fast version, the FFT). The DFT is defined, its relationship with the Fourier transform and series expansion is discussed, and two of the main applications of the DFT are presented: spectral analysis and filtering.
3) Design of frequency-selective filters. This topic provides design mechanisms for one of the most common types of filters in practice: frequency-selective filters. Focusing on the low-pass filters, some methods are provided for designing finite impulse response (FIR) filters and infinite impulse response (IIR) filters. Finally, some of the main structures used for the building of filters in practice (both in hardware and software).

In addition to these three topics, the course has a laboratory (5 simulation sessions carried out with Matlab) which reviews the main concepts of each topic.

List of topics to be covered

1. Digital processing of continuous signals
    - 1.1. Introduction
    - 1.2. Continuous signal sampling
    - 1.3. Discrete-time processing of continuous signals
    - 1.4. Continuous-time processing of discrete signals
    - 1.5. Changing the sampling rate
2. The discrete Fourier transform (DFT)
    - 2.1. Introduction
    - 2.2. DFT: Definition, calculation, relationships and properties
    - 2.3. Introduction to spectral analysis using DFT
    - 2.4. Filtering signals using the DFT
3. Filter design
    - 3.1. Introduction
    - 3.2. FIR filter design
    - 3.3. IIR filter design
    - 3.4. Comparison between design methods and filter types
    - 3.5. Structures for the implementation of digital filters

Prerequisites or co-requisites

- Calculus I
- Lineal Algebra
- Calculus II
- Signals and Systems

Specific goals for the course

Specific outcomes of instruction

- RA126 – To apply the DFT to the linear convolution with a long sequence.
- RA102 – To perform the convolution of signals.
- RA105 – To make an analysis on frequency of discrete time signals.
- RA115 – To link continuous time systems and systems of discrete time in the time domain.
- RA101 – To perform basic operations with signals and functions.
- RA108 - Ability to characterize LTI systems of discrete time in the time domain (response to the impulse and linear difference equation with constant coefficient) and processed domains (frequency and function of system response).
- RA114 – To link time continuous signals and time discrete time-domain signals.
- RA129 – To describe the characteristics of the spectral estimation of sequences with the spectrum of the continuous-time signal where they come.
- RA136 – To describe the basic methods for the design of FIR filters.
- RA143 – To characterize and describe mathematically IIR filters.
- RA145 – To design IIR filters using the bilinear transformation method.
- RA155 – To apply the rational change of the sample rate to the solution of problems.
- RA156 – To handle mathematical tools of analysis and design for discrete time systems.

- RA150 – To represent the flowchart of digital filters in their basic forms.
- RA107 – To calculate the signal spectrum ideally sampled.
- RA153 – To determine the parameters of an interpolator.
- RA106 – To characterize mathematically the operation of sampling of continuous-time signals.
- RA100 - Analysis and characterization of discrete time signals.
- RA112 - Ability to describe the block diagram of a digital signal processing system in real time enumerating the significant parameters of each block.
- RA128 – To describe the properties of DFT in the spectral analysis of sequences.
- RA134 – To differentiate the types of digital filters according to the characteristics of their impulse response: FIR and IIR filters.
- RA119 – To define the discrete Fourier transform (DFT).
- RA124 – To connect the linear and the circular convolutions.
- RA141 – To design the FIR filters through the windowing method.
- RA113 – To connect the time continuous signals and time discrete signals in the time domain.
- RA125 – To link the linear convolution with the DFT.
- RA135 – To describe the basic methods to design FIR filters.
- RA137 – To describe linear-phase FIR filters.
- RA138 – To differentiate the types of linear-phase FIR filters.
- RA139 – To describe the characteristics of the different linear-phase FIR filters.
- RA142 – To describe the principles of frequency sampling-based FIR filter design and to link it with DFT.
- RA144 – To design IIR filters through the impulse-invariant transformation.
- RA154 – To determine the parameters of a decimator.
- RA116 – To connect the continuous time systems and the discrete time systems in the frequency domain.
- RA120 – To connect the DFT with some other transforms: Fourier transform, Fourier series.
- RA121 – To determine the circular convolution of the sequences.
- RA127 – To apply DFT in the spectral analysis of sequences.
- RA132 – To define what is a digital filter.
- RA122 – To connect the circular convolution with DFT.
- RA133 – To describe the utilities of a digital filter.
- RA146 – To describe the differences, advantages and disadvantages, and selection criteria for the design method of a digital filter.
- RA152 – To set out the solution for the problems of change of the sampling rate.
- RA103 – To determine the connection between the different ways of characterizing LTI systems.
- RA98 – To characterize and analyze the discrete time LTI systems and signals in the frequency and transform domains.
- RA111 – To characterize the different types of systems according to their frequency discrimination.
- RA123 – To describe, develop and apply the linear convolution methods for the long sequences.
- RA96 - To characterize and analyze mathematically the discrete and continuous time LTI systems and signals in the time domain.

Further reading and supplementary materials
– James F. Kurose, Keith W. Ross. Computer Networking: A Top-Down Approach Pearson Addison Wesley, 2012. – Douglas E. Comer Internetworking with TCP/IP Volume One. Prentice Hall, 2013. – Andrew S. Tanenbaum, David J. Wetherall Computer Networks. Pearson Education International, 2010. – William Stallings Data and Computer Communications. Prentice-Hall International, 2007. – The Internet Engineering Task Force (IETF) Request For Comments (RFC): https://www.ietf.org/rfc.html – Moodle.