COURSE DESCRIPTION CARD - SYLLABUS

Course name
Signal processing [S1AiR2P>PS]

Course

Field of study
Automatic Control and Robotics

Year/Semester
2/3

Area of study (specialization)
–

Profile of study
practical

Level of study
first-cycle

Course offered in
Polish

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
30

Laboratory classes
15

Other
0

Tutorials
15

Projects/seminars
0

Number of credit points

4,00

Coordinators

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Lecturers

Prerequisites

The student starting this course should have basic knowledge of mathematics and statistics. Should have computer skills, spreadsheet skills, and be willing to learn to use other computer programs such as Matlab. The student should be able to obtain information from the indicated sources. Should also understand the need to expand his/her competences, be able to search for information sources and be ready to cooperate within the team. In addition, in terms of social competences, the student must present attitudes and features such as: honesty, responsibility, perseverance, cognitive curiosity, creativity, creative thinking, diligence, reliability, personal culture, good upbringing, respect for other people, care for laboratory equipment.

Course objective

1. Provide students with the basics of knowledge about signal processing techniques and teach how to use this knowledge in practice. 2. Developing students' problem-solving skills related to the selection of appropriate signal processing techniques for specific purposes with the use of computer systems. 3. Teaching the correct application of methods of signal analysis and processing.

Course-related learning outcomes

Knowledge:
The student acquires knowledge in the field of mathematics including algebra, geometry, analysis, probability and elements of discrete mathematics and logic (K1_W1, K1_W5), including mathematical methods and numerical methods necessary for: description and analysis of the properties of linear and basic nonlinear dynamic and static systems, description and analysis of complex quantities, description of random processes and uncertain quantities, description and analysis of combinational and sequential logic systems, description of algorithms of control and analysis of the stability of dynamic systems, description, analysis and methods of signal processing in the time and frequency domain, numerical simulation of dynamic systems in the domain of continuous time and discrete time. The student also acquires basic knowledge of the operation and use of IT tools for these purposes (K1_W10).

Skills:
As a result of the course, the student should demonstrate skills in the use of basic methods of signal processing and analysis in the time and frequency domain and extract information from the analyzed signals (K1_U9).

Social competences:
The student is ready to critically assess the acquired knowledge, understands and feels the need for continuous training and improvement of professional, personal and social competences, can inspire and organize the learning process of other people (K1_K1). He/she is also aware of the need for a professional and responsible approach to technical issues, scrupulous reading of the documentation and environmental conditions of the used devices. Moreover, he/she is ready to follow the rules of profession ethics and requires it from others, respects the diversity of views (K1_K5).

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Formative assessment:
a) in the field of lectures - on the basis of answers to questions about the material discussed in previous lectures,
b) in the field of laboratories/tutorials - on the basis of the assessment of the knowledge and understanding of the current issues presented in the course.
Summative assessment:
a) in the field of lectures, verification of the assumed learning outcomes is carried out by: assessing the knowledge and skills shown in the problem-based test,
b) in terms of tutorials, verification of the assumed learning outcomes is carried out by: assessing the student's preparation for individual classes, continuous assessment, at each class (oral answers) - rewarding the increase in the ability to use the learned principles and methods, assessment of solving tasks partially solved during classes and partially after their completion, the assessment of knowledge and skills related to solving tasks through a final test,
c) in the field of laboratories, verification of the assumed learning outcomes is carried out by: assessing the student's preparation for individual laboratory classes and assessing the skills related to the implementation of laboratory exercises, continuous assessment, during each class (oral answers) - rewarding the increase in the ability to use the learned principles and methods, evaluation of the report partially prepared during the classes, and also after their completion (this evaluation also takes into account the ability to work in a team of 2-3 people).
There is a possibility of obtaining additional points for activity during classes, in particular for:
- discussing additional aspects of the issue, the effectiveness of applying the acquired knowledge when solving a given problem,
- the ability to cooperate as part of a team practically implementing a detailed task in the laboratory,
- comments related to the improvement of teaching materials, indicating perceptual difficulties of students, enabling ongoing improvement of the teaching process.

Programme content

The program content of the Signal Processing subject includes basic knowledge of signals, their types and classification, their recording, filtration, separation and methods of their processing and transmission.

The lecture program includes the following topics:
1. Basic signal parameters (DC and AC components of the signal, energy, signal power and RMS value of

signal, orthogonal signals, signal correlation coefficient, standard deviation and signal variance, covariance matrix, signal histogram, energy and power signal normalization, center and length of signal, signal level).
2. Signal energy and power (finite and infinite in time signals, periodic signals, orthogonal signals, signal sum power and orthogonal signals).
3. Fourier series and transformations (the concept of signal transformation, Fourier series, Fourier series in complex form - signal spectrum (DFS), Gibbs effect, Fourier transformation (FT), Parseval-Rayleigh theorem, examples of Fourier transformation, impulse (Dirac pseudofunction), Discrete Time Fourier Transformation (DtFT), Discrete Fourier Transformation (DFT), Multivariate Fourier Transformation).
4. Representation of continuous signals (Laplace transformation and Fourier transformation, limit theorems, transient and steady state responses in automation systems).
5. Discrete Fourier Transformation (DFT) (variants of DFT, "butterfly" of two-point DFT, computational complexity of DFT, fast Forurier transformation (FFT) - "divide and conquer", distribution of DFT samples on the complex plane, signal distribution on harmonics, optical Fourier transformation, computing DFT in Matlab environment, two- and multidimensional DFT, standard and optical 2D DFT transformation, discrete trigonometric transformations (DTTs), discrete cosine transformations (DCTs), discrete sine transformations (DSTs), JPEG image compression standard).
6.Signal sampling (example of digital photography, sampling concept and process, non-ideal sampling, sampled signal spectrum, continuous signal recovery - sampling theorem, signal sampling, perfectly sampled signal spectrum, Fourier representation, two interpretations of the spectrum of a discrete signal, strict formulation of sampling theorem, sampling of band signals, reconstruction of a continuous signal, Kell coefficient).
7. Interpretations of Shannon's theorem (cardinal series, aliasing and strobe effect).
8. Quantization of signals (digital signal - binary stream, quantization noise, compression and expansion, differential PCM representation, delta modulation, pulse width modulation (PWM), sigma-delta modulation).
9. Binary representations of signal samples (can computers be trusted indiscriminately?, binary representations of natural numbers, octal and hexadecimal representations of numbers, "negative" bits - binary representations of integers, CSD code, numbers and calculations in the U2 code, conversion of integers to binary system, maximal digit's complement and positional system base, BCD codes, fractional representations, Qn format, floating point representations).
10. Convolution (continuous convolution, discrete linear and circular convolution, convolution versus correlation, geometric interpretation, linear system response, determination of the convolution by DFT method).
11. Z transformation (continuous-analog world versus discrete-digital world, concept of Z transformation, regions of convergence of Z transformation, uniqueness of right-hand Z transformation, Laurent series, holomorphic functions and Cauchy-Riemann equations, residuum, theorem about residues, properties of Z transformation, limit theorems, Z transform table, signal convolution and convolution transform, inverse Z transformations).
12. Discrete dynamical systems (concept and properties of linear stationary discrete systems, stability of a discrete system, description of linear stationary discrete systems, convolution of discrete signals, structures of digital filters, recursive digital filters - filters with infinite impulse response (IIR), non-recursive digital filters - filters with finite impulse response (FIR), basic implementations of digital filters).
13. Random signals and signal correlations (the concept of a random variable, the concept of a stochastic process, ergodic stochastic process, sequence of autocorrelation, covariance, basics of estimation, estimators of the correlation function).
14. Filtering of discrete signals (description of digital filters, recursive digital filters (IIR filters), non-recursive digital filters (FIR filters), basic (direct) realizations of IIR digital filters, signal flow graphs and Mason's formula, cascade and parallel realizations of IIR filters, description of discrete systems in the state space, implementations of digital FIR filters, FIR filters with linear phase characteristics, advantages and disadvantages of FIR filters compared to IIR filters).
15. Hurwitz polynomials (notion of Hurwitz polynomial and modified Hurwitz polynomial, necessary conditions to be met by the Hurwitz polynomial, Hurwitz stability criterion, Routh stability criterion, test fraction, test fraction realizability criterion as an LC immittance).
The tutorials program includes the following topics:
1. Basic parameters of signals.
2. Fourier series and transformations.
3. Representation of continuous signals (Laplace transform).
4. Discrete Fourier Transformation (DFT).
5. Signal sampling.

6. Signal quantization.
7. Written test.
Laboratory classes are conducted in the room equipped with modern teaching stations from National Instruments (USA), which include ELVIS II (Educational Laboratory Virtual Instrumentation Suite) measurement systems with Emona DATEx boards dedicated to this course. These systems cooperate with PC computers via specialized software - the so-called virtual measurement instruments operating in the LabVIEW environment. During the course, students use a variety of measuring devices for signal examining and analysis, e.g., a virtual spectrum analyzer, frequency characteristics (Bode) analyzer, as well as a virtual oscilloscope. They get acquainted in practice with the operation of basic circuits and functional blocks related to signal processing, such as the sampling and hold (S&H) circuit, multiplier, adder with adjustable weight coefficients, phase shifter, comparator, white noise generator, tunable filters, PCM encoder/decoder, signal and sequence generators). The laboratory program includes the following topics:
1. Introduction to the Emona DATEx equipment.
2. Determining signal parameters.
3. Sampling and reconstruction.
4. Studying of the aliasing.
5. PCM coding and decoding.
6. Noise and SNR parameters.
7. Detection of digital signals in the transmission channel.

Course topics

The lecture program includes the following topics:
1. Basic signal parameters (DC and AC components of the signal, energy, signal power and RMS value of signal, orthogonal signals, signal correlation coefficient, standard deviation and signal variance, covariance matrix, signal histogram, energy and power signal normalization, center and length of signal, signal level).
2. Signal energy and power (finite and infinite in time signals, periodic signals, orthogonal signals, signal sum power and orthogonal signals).
3. Fourier series and transformations (the concept of signal transformation, Fourier series, Fourier series in complex form - signal spectrum (DFS), Gibbs effect, Fourier transformation (FT), Parseval-Rayleigh theorem, examples of Fourier transformation, impulse (Dirac pseudofunction), Discrete Time Fourier Transformation (DtFT), Discrete Fourier Transformation (DFT), Multivariate Fourier Transformation).
4. Representation of continuous signals (Laplace transformation and Fourier transformation, limit theorems, transient and steady state responses in automation systems).
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transformation, regions of convergence of Z transformation, uniqueness of right-hand Z transformation, Laurent series, holomorphic functions and Cauchy-Riemann equations, residuum, theorem about residues, properties of Z transformation, limit theorems, Z transform table, signal convolution and convolution transform, inverse Z transformations).
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Teaching methods

1. Lecture: multimedia presentation, presentation illustrated with examples given on the board, solving problems, multimedia show, demonstration.
2. Tutorials: task solving, problem solving, case studies.
3. Laboratory classes: practical exercises, carrying out experiments, solving tasks, team working.

Bibliography

Basic:
1. Dąbrowski A., "Theory and signal processing" (in Polish), recorded lectures, www.put.poznan.pl, e-learning Moodle, open lectures, Poznan University of Technology, Poznań 2020 and teaching aids at www.dsp.put.poznan.pl
2. Dąbrowski A. et al., "Signal processing with the use of signal processors" (in Polish), Poznan University

of Technology Publishing House, Poznań 1998.
3. Florek A., Mazurkiewicz P., "Signals and dynamic systems. Interpretations - examples - exercises" (in Polish), Poznan University of Technology Publishing House, Poznań 2015.
4. Smith S.W., "Digital signal processing - practical handbook for engineers and scientists" (in Polish), BTC Publishing House, Warsaw 2007.
5. Lyons R.G., "Introduction to digital signal processing" (in Polish), WKŁ Publishing House, Warsaw 1999.
6. Szabatin J., "Signal theory basics" (in Polish), WKŁ Publishing House, Warsaw 2007.
7. Wojciechowski J., "Signals and systems" (in Polish), WKŁ Publishing House, Warsaw, 2008.
8. Zieliński T.P., "Digital signal processing: from theory to implementations" (in Polish), WKŁ Publishing House, Warsaw 2013.

Additional:
1. MitOpenCourseWare, Massachusetts Institute of Technology, http://ocw.mit.edu/ (courses: 6.011 "Introduction to Communication, Control, and Signal Processing", 6.003 "Signals and Systems").
2. Oppenheim A.V., Schafer R.W., "Digital signal processing" (in Polish), WKŁ Publishing House, Warsaw 1979.
3. Oppenheim A.V., Willsky A.S., Nawab S.H., "Signals & Systems", Pearson, 2016.

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,00
Classes requiring direct contact with the teacher	60	2,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	40	1,50