Ministry of Science and Higher Education of the Russian Federation
Federal State Autonomous Educational Institution of Higher Education
Perm National Research Polytechnic University

APPROVED BY
Pro-rector for Academic Affairs
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"25" _____ 2021

ACADEMIC COURSE WORKING PROGRAM

Academic course: Signal Filtering Theory
(Name)

Form of education: Full-time
(Full-time / part-time / correspondence)

Level of higher education: Bachelor's program
(Bachelor's program / Specialist program / Master's program)

Total labour intensiveness: 180 (5)
(Hours (CU))

Training program (degree): 15.03.06 Mechatronics and Robotics
(Code and denomination of degree)

Direction: Mechatronics and Robotics
(Title of curriculum)

Perm 2021

1 General Provisions

1.1 Goals and Objectives of the Course

The goal of the course is to study the theoretical foundations, principles of system operation and construction for evaluating and filtering electrical signals; presentation and description methods of random signals of mechatronic and robotic systems, the theory of random processes; filtering and signal extraction processing methods; to optimal evaluation methods of signal parameters; the main characteristics of signal evaluation and filtration quality, and the basic methods of synthesizing evaluation and filtering algorithms.

The objectives of the course are:

- to study basic methods of signal recept;
- to study criteria and limiting characteristics of data communication quality;
- to form the ability to apply the experimental research methods of mechatronic modules and robotic systems;
- to form the ability to apply methods of optimal solutions in mechatronic modules and robotic systems design;
- to master the skills of designing mechanical modules and robotic systems and complexes.

1.2 Prescribed Objects of the Course

Criteria and limiting characteristics of data communication quality.

1.3 Starting Conditions

Unstipulated

2 Planned Results of the Course Training

Competence	Indicator's Index	Planned Results of the Course Training (to know, to be able to, to master)	Indicator of Attaining Competence which the planned results of training are correlated with	Means of Assessment
PC-2.6	**IA-1**$_{\text{PC-2.6}}$	**To know** the principles of operation and construction systems of electric signal evaluation and filtering; presentation and description methods of random signals of mechatronic and robotic systems, theory of random processes.	**Knows** methods of determining functional indicators of flexible production systems.	Exam
PC-2.6	**IA-2**$_{\text{PC-2.6}}$	**To be able to** evaluate the signal parameters and the basic characteristics of the signal filtering quality.	**Is able to** calculate performance indicators for flexible production systems.	Laboratory work presentation
PC-2.6	**IA-3**$_{\text{PC-2.6}}$	**To master the skills** of applying filtering and signal extraction processing methods; methods of optimal signal parameters	**Has mastered the skills** of definition of functional indicators of flexible production systems.	Exam

		evaluation; basic methods of synthesizing evaluation and filtering algorithms.		

3 Full time and forms of academic work

Form of academic work	Hours in all	Distribution in hours according to semesters
		Number of semester
		5
1 Holding classes (including results monitoring) in the form: 1.1 Contact classwork, including:	56	56
- lectures (L)	18	18
- laboratory work (LW)	16	16
- practice, seminars and/or other seminar-type work (PW)	18	18
- control of self-work (CSW)	4	4
- test		
1.2 Students' self-work (SSW)	88	88
2 Intermediate attestation		
Exam	36	36
Grading test		
Test (Credit)		
Course Project (CP)		
Course Work (CW)	18	18
Workload in hours	**180**	**180**

4 Course contents

Name of the units with the course outline	**Full time of classroom activity in hours according to the forms**			**Full time of extracurricular work in hours according to the forms**
	L	**LW**	**PW**	**SSW**
5th semester				
Introduction	2	0	0	5
The subject, content and sequence of the course units, and its interaction with other subjects in the curriculum. Noise sources in electrical systems. Noise classification. Classification and examples of information acquisition models.				
Elements of random process theory	2	0	2	5
Elements of random process theory. Basic definitions, distribution functions, and quantitative characters.				
Correlation and spectral theory of random processes	2	2	2	10
Classification of random processes. Canonical decomposition of a random function. Physical interpretation of basic concepts of random processes. Stationary random processes. White noise and its				

characteristics.				
Convert random processes to linear and nonlinear systems	0	2	2	10
The basic theorems of probability theory. Probability distributions of random variables. Quantitative characters of random variables. Random processes and their characteristics. Correlation functions and their calculation. Spectral analysis of random processes.				
Models of signals and noise in radio engineering measurements	2	0	0	5
Models of analog electrical signals (radio signals), additive and non-additive noise. Fluctuation phenomena in radio engineering devices. Evaluation of likelihood functions for Gaussian signals.				
Experimental analysis methods of random signals and fields	0	2	0	5
Study of methods for defining the quantitative characters of random processes.				
Statistical methods for parameters evaluation	2	4	4	10
The content and classification of statistical measurement problems in radio engineering. Evaluation and filtering of signal parameters. Statistical criteria used in parameters evaluation.				
Filtering noisy signals	2	0	2	5
Criteria for the evaluation quality without priori information. Unbiasedness and minimum conditional dispersion. Cramér–Rao bound for evaluation error dispersion. Effective evaluation. Optimal properties of evaluation in the maximum likelihood. Anomalous errors and threshold effects in measurement. Methods of excluding uninformative parameters.				
Fundamentals of noise reduction theory for signals evaluation and filtering	2	2	4	13
Adaptive, robust and non-parametric algorithms for evaluating signal parameters. Kalman and Pugachev filtering theory. Multichannel receivers for evaluating the signal parameters.				
Elements of adaptive digital filter theory. Infinite impulse response (IIR) and finite impulse response (FIR) filters	2	0	2	10
Signal parameter discriminators. Measuring servosystems.				
Digital spectral analysis. Conclusion	2	4	0	10
Development of signal filtering and evaluation theory. Time-frequency signal processing. Wavelet filters and their application. Digital spectral analysis of random signals.				
Total with regard to 5th semester	**18**	**16**	**18**	**88**
Total with regard to the course	**18**	**16**	**18**	**88**

Topics of exemplary practical works

№	Topic of practical works
1	The basic theorems of probability. Distribution of random quantities probabilities. Quantitative characters of random quantities. Random processes and their characteristics.
2	Correlation functions and their calculation. Spectral analysis of random processes.
3	Effects of random processes on nonlinear instantaneous systems. Effects of random processes on linear systems.
4	Analysis of narrowband random processes. Impact of random processes on non-linear inertial chains.
5	Likelihood ratio and its application for synthesizing signal evaluation and filtering systems.
6	Optimal linear filtration. Filtering of changing signal parameters.
7	Non-linear evaluation of signal parameters.
8	Method of maximum likelihood. Synthesis of evaluations, optimal by the criterion of maximum likelihood.
9	Anti-correlated interference techniques, whitening filter.
10	Compensation method of noise reduction at signal evaluation and filtering.
11	Adaptive, robust and nonparametric algorithms for evaluating signal parameters.
12	Kalman and Pugachev filtering theory.
13	Multichannel receivers for evaluating signal parameters.
14	Signal parameter discriminators. Measuring servosystems.

Topics of exemplary laboratory works

№	Topic of laboratory works
1	Research methods of quantitative characters of random processes.
2	Research methods of noisy signal parameters evaluation.
3	Study of spectral signal processing using window functions.
4	Study of maximum likelihood method.

Topics of exemplary course project/work

№	Topic of course project/work
1	Development of speech filtering algorithms in telecommunication systems.
2	Development of evaluation algorithms of radar signal parameters.
3	Development of new and modification of existing trajectory signal filtering algorithms.
4	Study of the quality algorithms of signal evaluation and filtering.
5	Modeling of devices and algorithms for signal evaluation and filtering.
6	Application of devices and algorithms for signal evaluation and filtering on analog and digital technology.

5 Organizational and Pedagogical Conditions

5.1 Educational Technologies Used for Competences Formation

Holding lectures in the discipline is based on the active method of training in the process of which students are not passive but active participants of the lesson answering questions of the teacher. Teacher's questions are aimed at activating the process of learning material as well as at the development of logical thinking. The questions stimulating associative thinking and connecting new material with the previous one are formulated by the teacher in advance.

Practical lessons are held by realization of the method based on active training: problem areas are determined, groups are formed. The following aims are pursued in the process of practical education: use of definite disciplines knowledge and creative methods in solving problems and decision-making;

students' skill-building of teamwork, interpersonal communication and development of leadership skills; consolidation of the basic theoretical knowledge.
Laboratory classes are based on an interactive learning method in which students communicate not only with the teacher but also with each other. At the same time, students' activity in the learning process dominates. The teacher's place in interactive classes is reduced to orienting students' activities to achievement of the goals of studies.
Interactive lectures, group discussions, role-playing games, training sessions, and analysis of situations and simulation models are used in academic studies.

5.2 Students' Manual for the Course Study

Learning the course, it is advisable for students to implement the following recommendations:
1. Learning of the discipline should be done systematically.
2. After learning one of the course units with the help of the text-book or lecture notes it is recommended to reproduce the basic terms, definitions, notions of the unit from memory.
3. Special attention should be paid to the reports on practical studies and individual complex tasks for self-work.
4. The topics list for individual study is given by the teacher at the lectures. The teacher also provides students with literary sources (first of all, new ones in the periodical scientific literature) for a more detailed under-standing of the issues presented at the lectures.

6 List of Teaching Materials and Information Supply for Students' Self work in the Discipline

6.1 Paper-based courseware

№	Bibliographic entry (author, title, mode of publication, place, publishing house, year of publication, number of pages)	Number of copies in the library
1 Basic literature		
1	McClellan J., Schafer R., Yoder M. DSP First. – Pearson; 2nd edition, 2015. 592 p.	
2	Kozadaev K.V. Intelligent Information Technologies: textbook / K.V. Kozadaev. Minsk: BSU, 2020. 194 p.	
2 Additional literature		
2.1 Educational and scientific literature		
1	Zhmud V.A. Numerical Optimization of Regulators for Automatic Control System: Textbook for higher education / Vadim A. Zhmud, Lubomir V. Dimitrov , Jaroslav Nosek. Novosibirsk: NSTU Publisher, 2019. – 296 p.	
2.2 Standardized and Technical literature		
3 Students' manual in mastering discipline		
4 Teaching and learning materials for students' self-work		

6.2 Electronic Courseware

Kind of literature	Name of training tool	Reference to information resource	Accessibility of EBN (Internet / local net; authorized /

			free access)
Additional literature	Digital Signal Processing Proakis & Manolakis Solutions Manual	https://archive.org/details/DigitalSignalProcessingProakisManolakisSolutionsManual	internet, free access

6.3 License and Free Distributed Software used in the Course Educational Process

Type of Software	Software branding
Operating systems	Debian (GNU GPL)
Operating systems	Windows 10 (Azure Dev Tools for Teaching)
Office applications	LibreOffice 6.2.4. OpenSource, free
General purpose application software	MATHCAD 14 Academic, PNRPU 2009
General purpose application software	MATLAB 7.9 + Simulink 7.4 Academic, PNRPU 2009
Development, test, and debug environment	MS Visual studio 2019 community (Free)

6.4 Modern Professional Databases and Inquiry Systems Used in the Course Educational Process

Branding	Reference to information resource
Elsevier "Freedom Collection" database	https://www.elsevier.com/
Scopus database	https://www.scopus.com/
Scientific electronic library database (eLIBRARY.RU)	https://elibrary.ru/
Scientific Library of Perm National Research Polytechnic University	http://lib.pstu.ru/
Lan' Electronic library system	https://e.lanbook.com/
IPR books Electronic library system	http ://www.iprbookshop.ru/
Information resources of the Network ConsultantPlus	http://www.consultant.ru/
Information and Reference System of Regulatory and Technical Documentation "Technical Expert: Norms, Rules, Standards and Legislation of Russia"	https://техэксперт.сайт/

7 Logistics of the Course Educational Process

Type of classes	Name of the necessary basic equipment	Number of units
Course work	Personal computer	20
Laboratory class	Personal computer	20
Lecture	Projector, screen	1
Practical class	Personal computer	20

8 Fund of the Course Evaluating Tools

Described in a separate document