

MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION  
Federal State Autonomous Educational Institution for Higher Education  
«North-Caucasus Federal University»

**APPROVED BY**

Dean of FPE of NCFU  
Candidate of Technical Sciences,  
Associate Professor A.E. Verisokin

COURSE SYLLABUS  
**«Digital Signal Processing (DSP)»**

|                                 |                                                                           |
|---------------------------------|---------------------------------------------------------------------------|
| Field of study                  | <u>13.04.02 Electric Power Engineering and<br/>Electrical Engineering</u> |
| Specialization (Profile)        | <u>Intelligent Power Supply Systems</u>                                   |
| Year of commencement of studies | <u>2026</u>                                                               |
| Mode of study                   | <u>full-time</u>                                                          |
| Implemented in semester(s)      | <u>2</u>                                                                  |

**DEVELOPED BY:**

Candidate of Technical Sciences,  
Associate Professor of the Department of  
Automated Electric Power Systems and  
Power Supply, D.A. Kostyukov

## **1. Purpose and objectives of studying the discipline (module)**

The course «Digital Signal Processing» develops a systematic understanding of digital signal processing principles and practical application skills in future engineers. The course covers the fundamentals of discrete signal and system theory, methods of spectral analysis and filtering of discrete signals, discrete filter synthesis algorithms, the influence of quantization and finite-precision computations on the operation of digital devices, modulation methods used for digital data transmission, and adaptive filters and multi-rate signal processing.

The objective of course is to develop students' systematic theoretical knowledge and practical competencies in digital signal processing. Upon completion of this course, students should be able to:

- understand the basic methods of converting discrete (digital) signals and conduct their comparative analysis;
- possess theoretical knowledge of the discrete z-transform and the basic methods of synthesizing digital filters;
- implement various types of digital filters in software—digital filters using the DFT method, non-recursive digital filters, and recursive digital filters;
- be proficient in information technology and software for designing digital signal processing units and systems;
- navigate modern literature on digital signal processing and digital spectral analysis.

This course has an applied mathematical focus. Emphasis is placed on mastering basic digital signal processing algorithms, their interrelations, and areas of application. Emphasis is placed on developing skills in calculating the parameters of the discrete Fourier transform, z-transform, spectral signal analysis, digital filter synthesis, and multi-rate signal processing.

The main challenges in mastering the course include:

- successful mastery of this course requires a combination of knowledge in higher mathematics, discrete mathematics, and programming;
- the abstract nature of mathematical concepts (series, signal, complex series, convolution);
- the ability to select an appropriate method from a number of interrelated techniques requires an understanding of the internal logic of transformation algorithms and the properties of the signals being processed;
- mastering programming skills for implementing algorithms and using specialized libraries, which is an interdisciplinary task.
- effects associated with the finite accuracy of calculations, since often all the methods used have a numerical implementation.

## **2. Place of the discipline (module) in the structure of the educational program**

The discipline " Digital Signal Processing (DSP)" belongs to the part formed by the participants of educational relations within the educational program. It is studied in the 2th semester.

**3. List of planned learning outcomes for the discipline (module), mapped to the planned outcomes of the educational program**

| Competency code and formulation                                                                                                 | Indicator code and formulation                                                                                                                 | Planned learning outcomes for the discipline (module) describing the stages of competency and indicator formation |
|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| <b>PC-3</b> Capable of managing the power system operating mode of an electrical power supply system using digital technologies | <b>ID-3 PC-3</b> Applies knowledge of digital technologies in the processes of generation, transmission, and distribution of electrical energy | Capable of managing the power system operating mode of an electrical power supply system                          |

**4. Scope (credit load) of the academic discipline (module) and forms of control**

|                                                         |                          |
|---------------------------------------------------------|--------------------------|
| <b>Total study load:</b> 5 credits / 180 academic hours | <b>In academic hours</b> |
| <b>Contact work:</b>                                    | 54                       |
| Lectures / of which practical training                  | 0 / 0                    |
| Laboratory works / of which practical training          | 0 / 0                    |
| Practical classes / of which practical training         | 54 / 0                   |
| <b>Independent work</b>                                 | 90                       |
| <b>Forms of control:</b>                                |                          |
| Exam                                                    | —                        |
| Pass/Fail (Credit)                                      | 2th semester             |
| Graded Pass/Fail (Credit with grade)                    | 36                       |
| Course project/paper                                    | —                        |

\* The discipline (module) provides for the use of e-learning and distance educational technologies (unless otherwise stipulated by the educational standard).

**5. Content of the discipline (module), structured by topics (sections), indicating the number of hours and types of classes**

| № | Section (topic) of the discipline and brief content                                                                                                                                                                                                                                                              | Formed competencies and indicators | Full-time form                                                                                |                   |                  |                         | Forms of ongoing progress control |
|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-----------------------------------------------------------------------------------------------|-------------------|------------------|-------------------------|-----------------------------------|
|   |                                                                                                                                                                                                                                                                                                                  |                                    | Contact work of students with the teacher / of which in the form of practical training, hours |                   |                  | Independent work, hours |                                   |
|   |                                                                                                                                                                                                                                                                                                                  |                                    | Lectures                                                                                      | Practical classes | Laboratory works |                         |                                   |
| 1 | <b>Topic 1. Introduction to Digital Signal Processing.</b> Definitions and properties of discrete-time signals and systems. Classification of signals, elementary sequences, linearity, time invariance, causality and stability; role of DSP in intelligent power supply systems and measurement/control tasks. | ID-3 PC-3                          |                                                                                               | 4                 |                  | 4                       | Interview                         |
| 2 | <b>Topic 2. Sampling Theorem and Signal Reconstruction.</b> Sampling theorem and aliasing phenomena. Selection of sampling frequency, anti-aliasing filtering, quantization basics, reconstruction of continuous-time signals, and practical limitations of analog-to-digital and digital-to-analog conversion.  | ID-3 PC-3                          |                                                                                               | 2                 |                  | 6                       | Interview                         |

|   |                                                                                                                                                                                                                                                                                                         |           |  |   |  |   |           |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--|---|--|---|-----------|
| 3 | <b>Topic 3. Time-Domain Analysis.</b><br>Convolution and correlation operations for discrete signals. Linear convolution, circular convolution, impulse response, cross-correlation, autocorrelation, and interpretation of time-domain relationships in engineering signal analysis.                   | ID-3 PC-3 |  | 4 |  | 4 | Interview |
| 4 | <b>Topic 4. Difference Equations and System Representation.</b> Difference equations for discrete-time systems. Representation of digital filters and dynamic systems by input-output relations, block diagrams, impulse responses, recursion, and initial conditions used in numerical implementation. | ID-3 PC-3 |  | 2 |  | 6 | Interview |
| 5 | <b>Topic 5. Discrete Fourier Transform Theory.</b> Discrete Fourier Transform (DFT) theory and properties. Periodicity, symmetry, linearity, circular shift, convolution in the frequency domain, frequency resolution, and interpretation of the discrete spectrum of engineering signals.             | ID-3 PC-3 |  | 4 |  | 4 | Interview |

|   |                                                                                                                                                                                                                                                                                                  |           |  |   |  |   |           |
|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--|---|--|---|-----------|
| 6 | <b>Topic 6. Fast Fourier Transform Algorithms.</b> Fast Fourier Transform (FFT) algorithms and implementation. Radix-based decomposition, computational complexity reduction, data ordering, software implementation principles, and use of FFT methods for real-time spectral analysis.         | ID-3 PC-3 |  | 4 |  | 6 | Interview |
| 7 | <b>Topic 7. Spectral Analysis of Real Signals.</b> Spectral analysis of real signals: leakage and windowing techniques. Effects of finite observation intervals, choice of window functions, amplitude estimation, noise influence, and practical interpretation of spectra in monitoring tasks. | ID-3 PC-3 |  | 2 |  | 6 | Interview |
| 8 | <b>Topic 8. Z-Transform Fundamentals.</b> Z-transform definition, region of convergence, and properties. Relationship with the Fourier transform, poles and zeros, inverse z-transform, and use of z-domain methods for analyzing discrete-time systems.                                         | ID-3 PC-3 |  | 4 |  | 6 | Interview |

|    |                                                                                                                                                                                                                                                                                      |           |  |   |  |   |           |
|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--|---|--|---|-----------|
| 9  | <b>Topic 9. Transfer Functions and Stability Analysis.</b> Transfer functions and system stability analysis. Pole-zero representation, frequency response, causality, BIBO stability criteria, and evaluation of dynamic behavior of digital signal processing systems.              | ID-3 PC-3 |  | 2 |  | 6 | Interview |
| 10 | <b>Topic 10. FIR Filter Structures.</b> Finite Impulse Response filters: characteristics and structures. Linear phase conditions, impulse response length, direct and transposed forms, computational requirements, and typical applications of non-recursive digital filters.       | ID-3 PC-3 |  | 4 |  | 6 | Interview |
| 11 | <b>Topic 11. FIR Filter Design Methods.</b> FIR design methods: windowing, frequency sampling, and Parks-McClellan algorithm. Specification of passband and stopband requirements, ripple, transition bands, filter order estimation, and comparative analysis of design approaches. | ID-3 PC-3 |  | 4 |  | 6 | Interview |
| 12 | <b>Topic 12. IIR Filter Structures.</b> Infinite Impulse Response filters: structures and stability. Recursive filter realization, canonical forms, cascade and parallel sections, sensitivity to coefficient quantization, and stability constraints in digital implementation.     | ID-3 PC-3 |  | 4 |  | 6 | Interview |

|    |                                                                                                                                                                                                                                                                                     |           |  |   |  |   |           |
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| 13 | <b>Topic 13. IIR Filter Design Methods.</b> IIR design methods: bilinear transformation and impulse invariance. Analog prototype filters, frequency prewarping, mapping of s-plane characteristics to the z-plane, and practical comparison of recursive filter design techniques.  | ID-3 PC-3 |  | 2 |  | 6 | Interview |
| 14 | <b>Topic 14. Adaptive Filtering.</b> Adaptive filtering: LMS algorithm and applications. Error minimization, step-size selection, convergence behavior, adaptive noise cancellation, system identification, and application of adaptive filters in measurement and control systems. | ID-3 PC-3 |  | 4 |  | 6 | Interview |
| 15 | <b>Topic 15. Multirate Signal Processing.</b> Multirate signal processing: decimation, interpolation, and filter banks. Sampling-rate conversion, anti-imaging and anti-aliasing filters, polyphase concepts, and use of multirate methods in efficient DSP architectures.          | ID-3 PC-3 |  | 4 |  | 6 | Interview |

|    |                                                                                                                                                                                                                                                                                                                  |           |  |           |  |           |           |
|----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--|-----------|--|-----------|-----------|
| 16 | <b>Topic 16. Modern Applications and Real-Time DSP.</b> Modern applications: DSP for AI/ML and real-time implementation. Feature extraction, preprocessing of measurement data, embedded DSP platforms, latency constraints, and integration of digital signal processing into intelligent power supply systems. | ID-3 PC-3 |  | 4         |  | 6         | Interview |
|    | <b>TOTAL</b>                                                                                                                                                                                                                                                                                                     |           |  | <b>54</b> |  | <b>90</b> |           |

## **6. Assessment tools for ongoing progress control and intermediate assessment of students in the discipline (module)**

The goal of mastering the discipline is to develop students' ability to apply fundamental and applied methods of digital signal processing to the analysis, transformation, spectral representation, filtering, software implementation, and interpretation of discrete signals and systems used in electric power engineering, electrical engineering, measurement, diagnostics, control, and intelligent power supply systems.

The objectives of the discipline are to study the principles and properties of discrete-time signals and systems; to master sampling, reconstruction, aliasing, convolution, correlation, difference equations, the discrete Fourier transform, fast Fourier transform algorithms, and the z-transform; to develop skills in spectral analysis of real signals, including leakage and windowing effects; to form practical competencies in the synthesis, stability analysis, and software implementation of FIR and IIR digital filters; to understand the influence of quantization and finite-precision computations on digital devices; and to prepare students for applying adaptive filtering, multirate signal processing, filter banks, and modern real-time DSP tools in engineering tasks.

## **7. Methodological guidelines for students on mastering the discipline**

When starting work, each student should take into account the following provisions.

The discipline (module) is organized thematically; each topic represents a logically complete section.

Practical classes are conducted to consolidate the acquired information and develop skills in applying it to solve practical problems in the relevant subject area.

Students' independent work is aimed at independently studying additional material, preparing for practical and laboratory classes, as well as completing all types of independent work.

For successful mastery of the discipline, it is necessary to complete all types of independent work using the recommended information sources.

## **8. Educational, methodological, and informational support of the discipline**

### **8.1. List of basic and additional literature required for mastering the discipline (module)**

#### **8.1.1. List of basic literature:**

1. L. Tan and J. Jiang, Digital Signal Processing: Fundamentals and Applications, 2nd ed. – Waltham, MA: Academic Press, 2013.
2. Oppenheim A.V., Schaffer R.W. Discrete-Time Signal Processing. 3rd ed. – Upper Saddle River, NJ: Prentice Hall, 2010.
3. Proakis J.G., Manolakis D.G. Digital Signal Processing: Principles, Algorithms, and Applications. 4th ed. – Upper Saddle River, NJ: Prentice Hall, 2006.
4. Lyons R.G. Understanding Digital Signal Processing. 3rd ed. – Upper Saddle River, NJ: Prentice Hall, 2011.
5. Mitra S.K. Digital Signal Processing: A Computer-Based Approach. 4th ed. – New York: McGraw-Hill, 2011.

#### **8.1.2. List of additional literature:**

1. Haykin S. Adaptive Filter Theory. 5th ed. – Upper Saddle River, NJ: Prentice Hall, 2014.
2. Vaidyanathan P.P. Multirate Systems and Filter Banks. – Upper Saddle River, NJ: Prentice Hall, 1993.

### **8.2. List of educational and methodological support for students' independent work in the discipline (module)**

1. Methodological Guidelines for Practical Classes in the Discipline « Digital Signal Processing (DSP)» for Students in the Field of Study 13.04.02 Electric Power Engineering and Electrical Engineering / Compiled by D.A. Kostyukov. – Stavropol: North-Caucasus Federal University, 2026.
2. Methodological Recommendations for Organizing Independent Work of Students in the

### 8.3. List of resources of the information and telecommunications network "Internet" necessary for mastering the discipline (module)

1. <http://biblioclub.ru> Electronic Library System «University Library Online»
2. <http://catalog.ncstu.ru> Electronic Catalog of the Association of Electronic Libraries of Educational Institutions and Organizations of the North Caucasus Federal District
3. <http://www.iprbookshop.ru> Electronic Library System IPR SMART
4. <http://window.edu.ru/> Unified Window of Access to Educational Resources
5. <http://openedu.ru> National Online Learning Portal «Open Education»
6. <https://www.iec.ch> Official website of the International Electrotechnical Commission (IEC) – access to IEC standards and technical resources
7. <https://ieeexplore.ieee.org> IEEE Xplore Digital Library – access to IEEE standards, journals and conference papers on digital signal processing, spectral analysis, digital filters, adaptive filtering, embedded DSP systems, measurement data processing, diagnostics, and smart grid signal processing applications.
8. <https://minenergo.gov.ru/> Official website of the Ministry of Energy of the Russian Federation

### 9. List of information technologies used in the educational process for the discipline (module), including the list of software and information reference systems

During lectures, computer equipment and presentation of multimedia materials are used. In seminar and practical classes, students present presentations prepared by them during independent study hours.

Information reference systems:

Information reference and information legal systems used in the study of the discipline:

|   |                                                                                                                          |
|---|--------------------------------------------------------------------------------------------------------------------------|
| 1 | ConsultantPlus – <a href="http://www.consultant.ru/">http://www.consultant.ru/</a>                                       |
| 2 | <a href="https://minenergo.gov.ru/">https://minenergo.gov.ru/</a> – Official website of the Ministry of Energy of Russia |

Software:

|   |                          |
|---|--------------------------|
| 1 | Alt Workstation 10       |
| 2 | Alt Workstation K        |
| 3 | Alt Server               |
| 4 | Office suite – R7-Office |

### 10. Description of the material and technical base necessary for the implementation of the educational process in the discipline (module)

|                   |                                                                                                                                                                                                          |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Practical classes | Classroom for conducting training sessions, equipped with multimedia equipment and technical teaching aids.                                                                                              |
| Independent work  | A room for independent work of students, equipped with computer equipment with the ability to connect to the Internet and access to the university's electronic information and educational environment. |

## **11. Features of mastering the discipline (module) by persons with disabilities**

Students with disabilities are provided with special textbooks, teaching aids and didactic materials, special technical means of learning for collective and individual use, services of an assistant who provides students with the necessary technical assistance, as well as sign language interpreting and typhlo-sign language interpreting services.

Mastering the discipline (module) by students with disabilities may be organized together with other students, as well as in separate groups.

Mastering of the discipline (module) by students with disabilities is carried out taking into account the characteristics of psychophysical development, individual capabilities and health status.

In order to ensure accessibility of higher education under the educational program for persons with disabilities when mastering the discipline (module), the following is provided:

### **1) For persons with visual disabilities:**

- presence of an assistant who provides the student with the necessary technical assistance taking into account individual characteristics (helps to take a seat, move around, read and complete the task, including writing under dictation);
- written assignments, as well as instructions on the procedure for their completion, are formatted in enlarged font;
- special textbooks, teaching aids and didactic materials (with large print or audio files);
- individual uniform lighting of at least 300 lux;
- if necessary, a magnifying device is provided to the student for completing the task.

### **2) For persons with hearing disabilities:**

- presence of an assistant who provides the student with the necessary technical assistance taking into account individual characteristics (helps to take a seat, move around, read and complete the task, including writing under dictation);
- provision of collective sound amplification equipment; if necessary, the student is provided with individual sound amplification equipment;
- provision of appropriate sound means of information reproduction.

### **3) For persons with musculoskeletal disorders (including those with severe motor impairments of the upper limbs or absence of upper limbs):**

- written assignments are performed on a computer with specialized software or dictated to an assistant;
- at the student's request, assignments may be completed orally.

## **12. Features of implementing the discipline using distance educational technologies and e-learning**

According to Part 1 of Article 16 of Federal Law No. 273-FZ of December 29, 2012 "On Education in the Russian Federation," e-learning is understood as the organization of educational activities using information contained in databases and used in the implementation of educational programs, information technologies and technical means that ensure its processing, as well as information and telecommunications networks that ensure the transmission of said information through communication lines and the interaction of students and teaching staff. Distance educational technologies are understood as educational technologies implemented primarily using

information and telecommunications networks with indirect (remote) interaction between students and teaching staff.

The discipline may be implemented using distance educational technologies and e-learning in whole or in part. The components of the educational and methodological set of the discipline (syllabus, assessment and methodological materials, forms of certification) implemented using distance educational technologies and e-learning contain an indication of their use.

When organizing educational activities using distance educational technologies and e-learning, asynchronous and synchronous methods of interaction between participants in educational relations via the information and telecommunications network "Internet" may be provided.

When using distance educational technologies and e-learning, the schedule for the discipline indicates: methods of interaction between participants in educational relations via the information and telecommunications network "Internet" (VCS – video conferencing, ET – electronic testing); links to the electronic information and educational environment of NCFU, to educational platforms and resources of other organizations to which open access is provided via the information and telecommunications network "Internet"; for synchronous learning – the time of online classes and the instructors; for asynchronous learning – the authors of online courses.

When organizing intermediate assessment using distance educational technologies and e-learning, the Methodological Recommendations on the use of technical means ensuring the objectivity of results during intermediate and state final assessment in higher education programs – bachelor's programs, specialist's programs and master's programs using distance educational technologies (Letter of the Ministry of Science and Higher Education of the Russian Federation dated December 7, 2020 No. MN-19/1573-AN "On sending methodological recommendations") are applied.

The implementation of the discipline using e-learning and distance educational technologies is carried out using the electronic information and educational environment of NCFU, to which students have access via the information and telecommunications network "Internet", or using resources of other organizations, including platforms that provide services for video conferencing, online meetings and distance learning (MTS-Link), as well as using the capabilities of social networks to facilitate communication between students and instructors.

The educational and methodological support of the discipline implemented using e-learning and distance educational technologies includes the syllabus, educational and methodological manuals or a lecture course, methodological guidelines for performing various types of learning activities provided for by the discipline, and other educational and methodological materials posted in the electronic information and educational environment of NCFU, all presented in electronic form.