Національний технічний університет України «КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ імені ІГОРЯ СІКОРСЬКОГО»	Radio Engineering Faculty Radio Engineering Department

Generation, Modulation, and Coding of Signals (PN-05)

Curriculum of the academic discipline (Syllabus)

Course details

Level of higher education	***First (bachelor's)***
Field of knowledge	*17 – Electronics, Automation, and Electronic Communications*
Special	*172 "Electronic Communications and Radio Engineering"*
Educational program	*"Information and Communication Radio Engineering"*
Status of discipline	*Compulsory (standard) (professional training cycle)*
Form of study	*Full-time (daytime)*
Year of training, semester	*3rd year (full term of study), 2nd year (accelerated term of study) autumn semester*
Scope of the discipline	*Total: (4.0 credits) 120 hours* *Lectures: 18 hours* *Practical classes: 18 hours* *Laboratory classes (computer workshops): 18 hours.* *Independent work by students: 66 hours.*
Semester control/control measures	*TCW, MT (5); CGW, HW, HCW (5), individual assignments for computer workshops, credit (5)*
Class schedule	https://schedule.kpi.ua/
Language of instruction	*Ukrainian*
Information about the course leader/teachers	*Lecturer: Senior Lecturer Oleg Pavlov (pavlov.oleg1@lll.kpi.ua)* *Practical classes: Senior Lecturer Oleg Pavlov (pavlov.oleg1@lll.kpi.ua)* *Laboratory: Senior Lecturer Oleg Pavlov (pavlov.oleg1@lll.kpi.ua)*
Course location	http://dtsp.kiev.ua, https://do.ipo.kpi.ua/course/view.php?id=6574

Curriculum

1. Description of the academic discipline, its purpose, subject matter, and learning outcomes

The discipline "Signal Generation, Modulation, and Coding" (hereinafter referred to as SGMC) belongs to the cycle of professional training of specialists of the first (bachelor's) level of higher education in the specialty 172 "Electronic Communications and Radio Engineering" and is compulsory (mandatory) and for the educational program "Information and Communication Radio Engineering."

The aim of the GMSC discipline is to develop students' competencies in the analysis and synthesis of radio signal conversion processes in radio engineering systems used for the effective transmission of information via radio and wired communication channels, as well as the use of signals and their processing for radar, radio control, telemetry, radio navigation, remote sensing, etc.

After completing the course, students should demonstrate the following learning outcomes:

KNOWLEDGE (the result of studying the phenomena and patterns of the objective world, which can be logically or factually justified and empirically or practically verified):

- the purpose and structure of modern radio engineering and telecommunications systems, and the processes that occur within them;
- classification of signal generation methods and their main properties;
- classification of signal encoding methods and their main properties;
- classification of signal modulation methods and their main properties;
- the relationship between control signals, radio signals, and the representation of modulated signals in the main frequency band;
- models of narrowband signals, analytical signal, complex envelope, quadrature components, and quadrature signal processing;
- time and spectral characteristics of signals with different types of modulation.

SKILLS (ability to perform activities, "trained to perform actions," formed by repeating an action and bringing it to automatism):

- synthesis of harmonic oscillations using various methods;
- synthesis of noise-like oscillations with different statistical characteristics;
- synthesis of complex waveforms;
- encoding digital signals with an analog-to-digital converter;
- encoding of binary digital signals;
- PCM signal encoding;
- modeling and research of passband modulation processes of analog control signals;
- modeling and research of baseband and passband modulation processes of digital control signals.

SKILLS (a mastered method of performing an action, which is ensured by a set of acquired knowledge and skills**,** and which makes it possible to perform an action not only in familiar conditions, but also in changed ones):

- synthesis of harmonic, noise-like, and functional signals;
- encoding signals from analog and digital sources;
- calculation of the temporal and spectral characteristics of baseband and passband modulated signals using different modulation methods by reducing them to a set of known cases;
- application of mastered methods and calculations to assess changes in signal properties during their conversion by radio-electronic devices;

- analysis and evaluation of the results of a model study of the characteristics of basic signals for the creation of devices with specified parameters.

After mastering the academic discipline, students must demonstrate program competencies (a range of issues in which they have good knowledge) and learning outcomes in accordance with the professional educational program "*Information and Communication* Radio Engineering" (see https://osvita.kpi.ua/op), including, but not limited to (according to the professional educational program introduced in the 2024/2025 academic year by order of the rector of Igor Sikorsky KPI No. NOD/434/2024 dated June 10, 2024):

General competencies (GC)

GC 2 — Ability to apply knowledge in practical situations.

GC 7 — Ability to learn and acquire modern knowledge.

Professional competencies (PC)

PC 4 — Ability to perform computer modeling of devices, systems, and processes using universal application software packages (actual PC in terms of the subjects studied and approaches used).

PC 19 — Ability to apply and analyze various types of signal modulation and coding in radio communication channels of modern information and communication radio frequency systems.

FC 20 — Ability to select random signal parameters and optimize the communication channel according to the required criteria in the presence of noise and interference, perform engineering calculations of the main characteristics of random signals and devices for their processing.

Program learning results (PLR)

PLR 13 — Apply fundamental and applied sciences to analyze and develop processes occurring in telecommunications and radio engineering systems (actual PLR in terms of the subjects studied and approaches applied);

PLR 27 — Select modulation parameters and apply methods of noise-resistant and efficient coding of information and communication radio systems (normative PLR according to section 5 of the OPS).

2. Prerequisites and post-requisites of the discipline (place in the structural-logical scheme of training under the relevant educational program)

2.1. The study of the GMCS academic discipline is based on the competencies acquired during the study of the following academic disciplines: "Higher Mathematics" (topics "Differentiation and Integration of Functions," "Functional Series," "Differential Equations," "Fourier Transform," "Probability Theory," "Theory of Complex Variable Functions"), "Physics" (topics "Electrostatics," "Electromagnetism"), "Materials and Components of Radio-Electronic Equipment" or "Circuit Engineering. Part 1. Electronic Component Base" (topic "Characteristics of Electronic and Semiconductor Devices"), "Circuitry. Part 2. Analog Circuitry" (topics "Elementary Amplifiers on Bipolar and Field-Effect Transistors," "Transistor Operation in Nonlinear Mode"), "Fundamentals of Circuit Theory" (topics "Oscillatory Circuits," "Coupled Circuits," "Circuit Functions"), "Fundamentals of Telecommunications and Radio Engineering Theory. Part 2. Signals and Processes in Radio Engineering."

2.2. The competencies acquired during the study of GMCS are used in the study of further disciplines of specialty 172 "Electronic Communications and Radio Engineering", such as "Design of Microwave Receiving Devices", "Electromagnetic Compatibility", "Mobile

Telecommunication Systems", "Signal Coding and Encryption," as well as during the completion of the diploma design project.

3. Contents of the course

Introduction. Processes of signal generation, coding, and modulation in radio engineering

Topic 00.1. Introduction. Processes of signal generation, coding, and modulation in radio engineering [1—4]; [1, pp. 5-9, 15-17]; [2, pp. 5-13, 21-24, 282-300]; [5, 6]:

- Purpose and objectives of the discipline GMCS. Discipline program.
- Block diagrams of the main functional components of a typical radio communication system (channel) (direct amplification and superheterodyne transmitters and receivers).
- Basic (typical) radio engineering processes of signal conversion using the example of a radio communication channel.
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Topic 00.2. Oscillation generation and generators. Terms and basic parameters [7—21]:

- Types of signal generators.
- Analog signal generators.
- Vector signal generators.
- Arbitrary waveform generators (ARB).
- Basic characteristics of a signal generator.
    - Phase noise and jitter.
    - Spurious emissions.
    - Frequency stability.
    - Level accuracy and level settling time.
    - Error vector magnitude (EVM).
    - Adjacent channel power (ACP).
    - Impedance matching (VSWR).

Section 1. Signal generation

Topic 01.1. Analog methods of generating harmonic oscillations [4, §24.1—§24.8, pp. 3—170], [2, §9.1-§9.11, pp. 270-299], [3, §14.4-§14.5, pp. 364-382]:

- Brief description of methods for analyzing nonlinear self-oscillating systems [4, §24.1, pp. 5–8]; [2, §9.1, pp. 270–273].
- The emergence of oscillations in an oscillator [4, §24.2, pp. 8–25]; [2, §9.2, pp. 273–276].
- Steady state of an oscillator [4, §24.3, pp. 25–34]; [2, §9.3, pp. 276–279].
- Soft and hard modes of generator operation [4, §24.4, pp. 34–54]; [2, §9.4, pp. 279–280].
- The influence of higher harmonics on the frequency and amplitude of generator oscillations. Stability of the frequency of oscillations at the generator output [4, §24.5, pp. 54–69].
- Transient mode of a sinusoidal generator. Method of slowly changing amplitudes [4, §24.6, pp. 69–96].
- Phase plane method [4, §24.7, pp. 965–127]; [2, §9.7, pp. 285–289].
- Some circuits of harmonic oscillators [4, §24.8, pp. 127–159]; [2, §9.5, pp. 280–282].

Topic 01.2. Digital methods of generating harmonic oscillations [22–49]:

- The 2nd order LRRPC method.
- PCS method.
- Polynomial method.
- CORDIC method.
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Topic 01.3. Digital methods of signal generation from LCM [22—49]:

- Control of GC parameters in the 2nd order LRRPC method.

- Control of GC parameters in the PCS method.
- Control of GC parameters in the polynomial method.
- Controlling GC parameters in the CORDIC method.

Topic 01.4. Digital methods of generating noise-like signals [50—65]:

- Congruent method.
- XORSHIFT method.
- MWC and SWC methods.
- Ziggurat method.
- Mersenne method.
- Fibonacci method.
- ZRA transformation.
- ACF estimation.
- PDF estimation.
- PSD estimation.
- Cryptographic methods and cryptographic resistance of PVP.
- Randomness tests.

Topic 01.5. Digital methods for generating arbitrary waveform signals [48—49]:

- LookUp table settings in the PCS method.
- Linear interpolation of tabular data.
- Spline interpolation of tabular data.

Section 2. Signal encoding during conversion and transmission in baseband

Topic 02.1. Concepts of data and signal encoding [70—100]:

- General interpretation of code and coding.
- Code and coding in data processing theory and data representation.
- Code and coding in computer programming and hardware device control.
- Code and coding in the theory of lossy and lossless data compression.
- Code and coding in cryptography.
- Code and coding in data transmission theory.
- Code and coding in mathematics and computer science.

Topic 02.2. Encoding of analog signals during their conversion and formatting [70—100]:

- linear binary code, binary-complement code, binary-decimal code, and 7-segment code in signal ADCs.
- Encoding according to the A- and μ-laws in speech ADCs.
- PCM, DPCM, APCM, ADPCM, DM.
- Pulse Modulation. PAM, PWM, PDM, PPM.
- Spectral signal coding, subband coding, adaptive transform coding.
- Source coding.

Topic 02.3. Coding of digital signals during their transmission in baseband (line coding) [70—100]:

- Types of linear codes. Polar, Uni-polar, Bipolar.
- Basic pulse shapes. NRZ, RZ, Manchester Line Code.
- Phase encoded.
- Multilevel binary.
- Duobinary Signaling, Coding and Decoding.

Topic 02.4. Data encoding during modulation (binary encoding & symbol mapping) [70—100]:

- Encoding binary data using Gray code when mapping it to a phase constellation.
- Mapping symbols onto a phase constellation in BPSK, QPSK, M-PSK, 16-QAM, 32-QAM.

Section 3. Analog methods of signal modulation in baseband and passband

Topic 03.1. Amplitude modulation (AM) of analog signals in passband. AM-DSB-FC, AM-DSB-SC, AM-SSB-FC, AM-SSB-SC [1, §7.1—§7.8, pp. 334—389]:

- Tonal AM (DSB-FC). Representation of signals in the time and frequency domains. Vector diagrams [1, §7.1, pp. 336–345].
- Energy characteristics of AM oscillations [1, §7.2, pp. 345–349].
- AM oscillations with an arbitrary signal [1, §7.3, pp. 349–357].
- Quadratic modulator [1, §7.3, pp. 357–358].

- Quadratic detector [1, §7.3, pp. 358–359].
- Balance (double sideband) modulation with carrier suppression (DSB-SC) [1, §7.4, pp. 359–361].
- Balanced modulator [1, §7.4, pp. 361–361].
- Synchronous (coherent) detection of oscillations with double sideband modulation [1, §7.4, pp. 361–367].
- Quadrature amplitude modulation (QAM) [1, §7.5, pp. 367–369].
- Single-sideband modulation (SSB) [1, §7.6, pp. 369–381].
  - Description of SSB signals in the frequency domain [1, §7.6, pp. 370–372].
  - Description of single-sideband modulated signals in the time domain [1, §7.6, pp. 372–379].
  - Method of generating single-band AM signals based on phase discrimination [1, §7.6, pp. 379–379].
  - Demodulation of single-sideband AM oscillations [1, §7.6, pp. 379–381].
- Single-sideband AM with incomplete (partial) suppression of the sideband — Vestigial sideband modulation (VSB) [1, §7.7, pp. 381–382].
- Description of signals with VSB modulation in the frequency domain [1, §7.7, p. 382].
- Generation of signals with VSB modulation [1, §7.7, pp. 382–386].
- Comparative analysis of signals and systems with amplitude modulation [1, §7.8, pp. 386–389].

Topic 03.2. Angle-modulated (AM) signals. Frequency modulation (FM) and phase modulation (PM) of analog signals in passband [1, §8.1–§8.8, pp. 395–481]:

- Angular modulation: basic concept [1, §8.1, pp. 396–400].
- Representation of signals with tonal angle modulation in the time domain [1, §8.2, pp. 400–404].
- Spectra of signals with tonal angular modulation ... [1, §8.3, pp. 404–423].
- Generation and detection of signals with angular modulation [1, §8.4, pp. 423–431].
- Angular modulation with a non-harmonic modulating signal [1, §8.5, pp. 431–437].
- Radio pulses with linear frequency modulation (LFM) [1, §8.6, pp. 437–452].
  - Radio pulse with LFM, its characteristics and properties [1, §8.6, pp. 437–439].
  - Spectrum of a radio pulse with linear frequency modulation [1, §8.6, pp. 439–448].
  - ACF of a radio pulse with LFM [1, §8.6, pp. 448–452].
- Radio signals with phase modulation (FMN) [1, §8.7, pp. 452–475].
  - ACF of radio pulses with phase modulation [1, §8.7, pp. 454–455].
  - ACF of Barker's FM signals [1, §8.7, pp. 455–457].
  - Spectra of FM signals of Barker [1, §8.7, pp. 457–561].
  - Generation of Barker FM signals [1, §8.7, pp. 461–461].
  - Binary pseudorandom sequence [1, §8.7, pp. 461–465].
  - Signals with phase modulation by binary pseudorandom sequences [1, §8.7, pp. 465–466].
  - ACF of signals manipulated by M-sequences [1, §8.7, pp. 466–470].
  - Spectra of signals manipulated by M-sequences [1, §8.7, pp. 470–475].

Section 4. Digital methods of signal modulation in baseband and passband

Topic 04.1. Amplitude modulation of digital signals in baseband [102–121].

- Amplitude manipulation (ASK), minimum required passband width,
- Quadrature amplitude modulation (QAM).

Topic 04.2. Frequency modulation of digital signals in baseband [102—121]:

- Frequency modulation (FSK), hard FSK and soft FSK,
- Binary FSK (BFSK), minimum required bandwidth, modulation index and FSK orthogonality conditions,
- M-position frequency shift keying (M-FSK),
- Minimum shift keying (MSK or MFSK), fast frequency shift keying (FFSK),
- Gaussian filter minimum frequency shift keying (GFSK).

Topic 04.3. Phase modulation of digital signals in baseband [102—121]:

- Phase shift keying (PSK), its types and characteristics,
  - Binary phase shift keying (BPSK, 2-PSK), minimum required bandwidth,
  - Quadrature phase shift keying (4-PSK, QPSK), transmitter and receiver structure for QPSK, bit error probability, time and spectral characteristics, minimum required passband width,
  - .... Differential quadrature phase shift keying (π/4-DQPSK),
  - Offset QPSK (OQPSK),
  - Square quadrature phase shift keying (SQPSK),
  - Shaped offset QPSK (SOQPSK),
  - .... Dual polarization quadrature phase shift keying (DPQPSK),
  - Higher-order PSK, M-position phase shift keying (M-PSK), Bit error rate (BER) in PSK,

- Differential phase shift keying (DPSK), its types and characteristics,
    - Differential coding in DPSK,
    - Differentially-encoded BPSK, or BPSK with differential encoding (DBPSK),
    - Symmetric differential phase shift keying (SDPSK),
    - Differentially encoded QPSK (DQPSK),
    - Symmetric differential quadrature phase shift keying (SDQPSK),
    - .... Probability of bit error for DPSK,
    - DPSK demodulation.

Topic 04.4. Continuous phase modulation of digital signals in baseband [102—121]:

- Continuous phase frequency shift keying (CPFSK),
- Continuous phase modulation (CPM).
- Minimum shift keying (MSK),
- Gaussian filter minimum shift keying (GFSK).

Topic 04.5. Lattice coded modulation of digital signals in baseband [102—121]:

- Phase manipulation using coded lattice (PSKTCM),
- General QAM modulation using binary data coding with a convolutional encoder (General QAMTCM),
- QAM modulation using rectangular QAM constellation and convolutional encoding of binary data (Rectangular QAMTCM).

Chapter 5. Access methods and wideband modulation

Topic 05.1. Frequency Division Multiple Access (FDMA) [122–138]:

- Frequency Division Multiple Access (FDMA) [5, §11.1.1, pp. 657–665, §11.4.1–11.4.3, 690–698], [6, §15-1, p. 842, §15-4, pp. 862–872]
- Time division multiple access (TDMA) [5, §11.1.2–11.1.4, pp. 665–672, §11.4.4, 704–708], [6, §15-1, p. 842]
- Code Division Multiple Access (CDMA) [5, §11.1.5, pp. 672–674, §12.7, 769–771, §12.8, 776–794], [6, §15-2, p. 843, §15-3, pp. 849–862]
    - The basic concept of CDMA,
    - Stages of CDMA modulation,
    - Codes used in CDMA,
    - Synchronous CDMA (CDM, code division multiplexing),
    - Asynchronous CDMA, Advantages of asynchronous CDMA over other methods,
    - Shared CDMA,
- Orthogonal Frequency Division Multiple Access (...................... OFDMA).

Topic 05.2. Data modulation using the OFDM method [122—138]:

- Comparison of the efficiency of single-carrier and multi-carrier systems.
- Idealized model of a system with OFDM modulation.
- OFDM modulation in the transmitter.
- OFDM demodulation in the receiver.
- DVB-T transmission system.

4. Teaching materials and resources

Basic recommended reading:

Main

1. Voloshchuk Yu.I. Signals and Processes in Radio Engineering (Part 1). Textbook for students of higher educational institutions, volume 1. – Kharkiv: SMIT Company, 2003. – 580 p.
2. Voloshchuk Yu.I. Signals and Processes in Radio Engineering (Part 2). Textbook for students of higher educational institutions, volume 2. – Kharkiv: SMIT Company, 2003. – 444 p.
3. Voloshchuk Yu.I. Signals and Processes in Radio Engineering (Part 3). Textbook for students of higher educational institutions: In 4 volumes. – Kharkiv: SMIT Company LLC, 2005. – Vol. 3: 528 p.
4. Voloshchuk Yu.I. Signals and Processes in Radio Engineering (Part 4). Textbook for students of higher educational institutions in 4 volumes. – Kharkiv: SMIT Company LLC, 2005. – Vol. 4: 496 p.

5. Sklar B. Digital Communication. Fundamentals and Applications, 2nd ed., 1032 p., Prentice Hall P T R Upper Saddle River, New Jersey 07458. – 1032 p.
6. Proakis J. Digital Communications. 4th ed., DJVU, Publishing House of Electronics Industry, China, 2001 – 937 p.

Additional

To the section "Signal Generation"

To the topic "Generation and oscillation generators. Terms and basic parameters"

7. Signal Generator Terminology and Specifications / NI, 2022-17 Oct, 10p.
8. Signal Generator. What are They. Circuit & Block Diagram / Electrical4U, 2020-10, 10p.
9. Key Characteristics of Signal Generators and Modulation Methods. Pocket Guide / R&S, 2022-11, 117p.
10. Modulation and Signal Generation with R&S Signal Generators. Educational Note - R&S, 2016-05, 120p,
11. Signal Generator Fundamentals / Tektronix, 2009-03, 54p.
12. XYZs of Signal Generators. Primer / Tektronix, 2016-07, 42p.
13. Szwoch G. Signal Generation on DSP / Gdańsk Univ. of Tech., Dep. of Multimedia Systems, 2021-01, 25p.
14. The Essential Signal Generator Guide. Building a Solid Foundation in RF. Part 1 / Keysight, 2022-06, 28p.
15. The Essential Signal Generator Guide. Building a Solid Foundation in RF. Part 2 / Keysight, 2019-01, 24p.
16. Understanding Phase Noise Needs and Choices in Signal Generation. AN / Keysight, 2018-01, 12p.
17. Selecting a Signal Generator. Technical Overview / Keysight, 2022-04, 28p.
18. Signal Generator Library. Module user's Guide. C28x Foundation Software / TI, 2011-09, 80p.
19. Signal generator design resources | TI.com
20. MathWorks - Signal Generation and Visualization - MATLAB & Simulink Example.
21. MathWorks - Signal generation using for loop - MATLAB Answers.

Related to "Generating harmonic oscillations using the second-order LRRPC method"

22. Development of harmonic oscillation generators and their testing on the ADSP-2181 simulator. For students of the Radio Engineering Faculty of all forms of training / Compiled by O.I. Pavlov, V.P. Smirnov, O.B. Sharpan. — Kyiv: NTUU "KPI", 2000. — 32 p.
23. ADSP21xx DSP Applications Using the ADSP-2100 Family. Vol. 1. Ch. 5. Digital Filters. 20 p.
24. Development of recursive filters in the DiFiDes package and their testing in the VisualDSP++ system. For students majoring in "172. Telecommunications and Radio Engineering" of all forms of training / Compiled by O.I. Pavlov, O.S. Zakharchenko. — Kyiv: NTUU "KPI", 2020. — 40 p.

On the topic "Generating PCM using the DDS method"

25. Direct Digital Synthesis Systems and Their Applications. For students of the Radio Engineering Faculty of all forms of training / Compiled by O.I. Pavlov, V.P. Smirnov. — Kyiv: NTUU "KPI", 2000. — 24 p.
26. Fundamentals of Direct Digital Synthesis (DDS) - ADI, MT-085. 2010-08, 9p.
27. Rick Cushing. Digital Signal Synthesis, 1999-Edu.-ADInc, 122p.
28. Rick Cushing. DDS (selective translation, Russian), 6p.
29. Walt Kester. High Speed DACs & DDS systems.
30. A Technical Tutorial on Digital Signal Synthesis - Ken Gentile & Rick Cushing, ADI, 1999.
31. AN-543 (High Quality, All-Digital RF Frequency Modulation Generation with the ADSP-2181 DSP and the AD9850 Direct Digital Synthesizer) – ADI, 1998-09, 6p.
32. AD9850E - Complete DDS Synthesizer - ADI, 1999, 19p.
33. Chemes E.O. Analysis of the Direct Digital Synthesis Method of High-Frequency Generators – Works of OPU, 2012, 6p.
34. Tyurin V.A. The PDS method in signal generators, 2015, 75p.
35. DDS - Direct Digital Frequency Synthesis. KT-2001-7-50, 5p.
36. DDS in test, measurement, and communication equipment. KT-2006-8, 4 p.
37. Kronin B. Signal generation using DDS - Circuitry and Design, 2012-01, 6 p.

Related to the topic "Generating FM by decomposing a function into a power series"

38. ADSP21xx DSP Applications Using the ADSP-2100 Family. Vol.1. Ch.4. Function Approximation. 20p.
39. Implementation of mathematical function approximation. For students majoring in "172. Telecommunications and Radio Engineering" of all forms of training / Compiled by O. I. Pavlov, O. S. Zakharchenko. — Kyiv: NTUU "KPI", 2020. — 19 p.
40. Polynomial approximation of the COS(x) function, pp. 25–26 / Solonina A.I., Ulakhovich D.A., Yakovlev L.A. Algorithms and processors for digital signal processing. — St. Petersburg: BHV-Petersburg, 2001. — 464 p.: ill.

Related to the topic "Generating GCs using the CORDIC method"

41. Volder J.E. The Cordic Trigonometric Computing Technique. IRE Transactions on Electronic Computer, 1959-09, pp. 330–334.
42. Meher P.K. [et al]. 50 Years of CORDIC: Algorithms, Architectures and Applications / IEEE Trans. on Circuits and Systems I: Regular Papers (2009-09-09). 56 (9): 1893–1907.
43. Phatak D.S. Double Step Branching CORDIC. A New Algorithm for Fast Sine and Cosine Generation / IEEE Transactions on Computers, v.47, No.5, 1998-05, pp.587-602.
44. Vladimirova T. Tiggeler H. FPGA Implementation of Sine and Cosine Generators Using the CORDIC Algorithm - Univ. of Surrey, 11p.
45. Use of the CORDIC vector rotation method, pp. 38-40 / Goldenberg L.M. et al. COS: Reference Book / L.M. Goldenberg, B.D. Matyushin, M.N. Polyak. — Moscow: Radio and Communications, 1985. — 312 p., ill.
46. Andraka, Ray (1998). A survey of CORDIC algorithms for FPGA based computers. ACM. North Kingstown, RI, USA: Andraka Consulting Group, Inc. 0-89791-978-5/98/01. Retrieved 2016-05-08.
47. Getting started with the CORDIC accelerator using STM32CubeG4 MCU Package. STMicroelectronics. Retrieved 2021-01-01.

Related to "Generation of functional signals and complex signals"

48. Pavlov O.I. Synthesis of LCM radio pulses using the DDS method on SP TMS320C2xx – MU to LR, 1996-11, 8p.
49. Pavlov O.I. Table-interpolation signal synthesis. Spline-interpolation model of EKS. — 2000-01, 13 p.

On the topic of "Pseudorandom sequence generation"

50. Methods of generating pseudo-random sequences and evaluation of their properties / O. A. Zamula, D. O. Semchenko // Applied Radio Electronics: Scientific and Technical Journal. – 2012. – Volume 11. No. 2. – P. 191–194.
51. Knut D. IP. T2, 3. Random numbers. 3.1. Introduction — 10 p.
52. Knut D. IP. T2, 3. Random numbers, 4. Arithmetic — 394 p.
53. Pavlov O.I. Synthesis of ShPS by the congruent method on SP TMS320C2xx — MU to LR, 1996-11, 8p.
54. ADSP21xx DSP Applications Using the ADSP-2100 Family. Vol.1. Ch.4. Function Approximation. 20p.
55. Linear congruent method — Wikipedia.
56. Random number generator — Widdow, AOS, pp. 417-423.
57. Random number generation — Schrufer E. Digital processing of discrete signals.
58. Schrufer E. Digital Processing of Discrete Signals: Textbook / Edited by V.P. Babak. — Kyiv: Lybid, 1992. — 296 p.
59. Xorshift - random number generators — Wikipedia.
60. Multiply-with-Carry pseudorandom number generator — Wikipedia.
61. Subtract-with-Carry — Wikipedia.
62. Ziggurat algorithm — Wikipedia.
63. Mersenne Twister - Wikipedia-en, Mersenne Twister - Wikipedia-de.
64. Cryptographic resistance — Hacking GPS using machine learning — Habr.
65. Soto J. Statistical Testing of Random Number Generators.

To the section "Signal Encoding"

To the topic "Basic concepts of coding theory"

66. Coding theory — Wikipedia, Coding theory — Wikipedia.
67. Data compression — Wikipedia, Data compression — Wikipedia.
68. Hamming R.W. Coding and Information Theory, 1986, 269p.
69. Mazurkov M.I. Fundamentals of Information Transmission Theory, 2005, 168c.
70. Hamming code — Wikipedia, Hamming codes — Wikipedia.

71. Gray code — Wikipedia, Gray code — Wikipedia.

To the section "Signal Coding"

72. Gray code — Wikipedia.pdf
73. Hamming codes — Wikipedia.pdf
74. Data compression — Wikipedia.pdf
75. Coding theory — Wikipedia.pdf
76. Coding theory - Wikipedia.pdf
77. Data compression - Wikipedia.pdf

To the section "Digital methods of signal modulation in baseband and passband"

78. Digital Baseband Modulation - MATLAB & Simulink — https://in.mathworks.com/help/comm/ug/digital-baseband-modulation.html
79. Symbol Mapping Examples - MATLAB & Simulink — https://in.mathworks.com/help/comm/ug/symbol-mapping-examples.html
80. Amplitude Modulation Examples - MATLAB & Simulink — https://in.mathworks.com/help/comm/ug/am-modulation-examples.html
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To the section "Access Methods and Broadband Modulation"

92. Modulation and Signal Generation with R&S Signal Generators. Educational Note - R&S, 2016-05, 120p,
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96. Lin P.G. OFDM Simulation in MATLAB (2010) orig
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101. Eric_Lawrey_PhD_Adaptive_Techniques_for_Multiuser_OFDM (2001)

102. Edited by Mazor Yu. L. et al. Radio Engineering. Encyclopedic Educational Reference Book. — Kyiv: Vyshcha Shkola, 1999

Manuals and methodological guidelines

103. Modeling of signals and processes in radio engineering in MathCAD and Multisim environments. Part 2. [Electronic resource]: textbook for students majoring in 172 "Telecommunications and Radio Engineering" /

Compiled by: O. V. Guseva, O. I. Pavlov; Igor Sikorsky Kyiv Polytechnic Institute. — Electronic text data (1 file, 3.173 MB). — Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2022. — 109 p. — https://drive.google.com/file/d/19IsfgO4dEm2i9C7bvV2PiGwgZmZPqV2k/view?usp=sharing

Information resources

104. SDN server of the Department of TOR on the discipline of GKMS at http://dtsp.kiev.ua and Course: Signal Generation, Modulation, and Coding | uiite — https://do.ipo.kpi.ua/course/view.php?id=6574 .

Educational content

5. Methodology for mastering the academic discipline (educational component)

Lectures

No	*Lecture topic and list of main questions*	*Hours*
	Introduction. Processes of signal generation, coding, and modulation in radio engineering	
1.	**Topic 00.1. Introduction. Processes** of signal generation, coding, and modulation in radio engineering **[1—4]; [1, pp. 5-9, 15-17]; [2, pp. 5-13, 21-24, 282-300]; [5, 6]:** • Purpose and objectives of the discipline GMCS. Discipline program. • Block diagrams of the main functional components of a typical radio communication system (channel) (direct amplification and superheterodyne transmitters and receivers). • Basic (typical) radio engineering processes of signal conversion using the example of a radio communication channel. •	1.0

1.2	**Topic 00.2.** Oscillation **generation and generators.** Terms and basic parameters **[7—21]:**
	• Types of signal generators.
	• Analog signal generators.
	• Vector signal generators.
	• Arbitrary waveform generators (ARB).
	• Basic characteristics of a signal generator.
	  ○ Phase noise and jitter.
	  ○ Spurious emissions.
	  ○ Frequency stability.
	  ○ Level accuracy and level settling time.
	  ○ Error vector magnitude (EVM).
	  ○ Adjacent channel power (ACP).
	  ○ Impedance matching (VSWR).
		1.0

	TOTAL	**2.00**
	Section 1. Signal generation	
2	**Topic 01.1. Analog methods of generating** harmonic oscillations [4, §24.1—§24.8, **pp. 3—170], [2, §9.1-§9.11, pp. 270-299], [3, §14.4-§14.5, pp. 364-382]:** • Brief description of methods for analyzing nonlinear self-oscillating systems [4, §24.1, pp. 5–8]; [2, §9.1, pp. 270–273]. • The emergence of oscillations in an oscillator [4, §24.2, pp. 8–25]; [2, §9.2, pp. 273–276]. • Steady state of an oscillator [4, §24.3, pp. 25–34]; [2, §9.3, pp. 276–279]. • Soft and hard modes of generator operation [4, §24.4, pp. 34–54]; [2, §9.4, pp. 279–280]. • The influence of higher harmonics on the frequency and amplitude of generator oscillations. Stability of the frequency of oscillations at the generator output [4, §24.5, pp. 54–69]. • Transient mode of a sinusoidal generator. Method of slowly changing amplitudes [4, §24.6, pp. 69–96]. • Phase plane method [4, §24.7, pp. 965–127]; [2, §9.7, pp. 285–289]. • Some circuits of harmonic oscillators [4, §24.8, pp. 127–159]; [2, §9.5, pp. 280–282].	2.0
3.1	**Topic 01.2. Digital methods of generating** harmonic oscillations [22–49]: • The 2nd order LRRPC method. • PCS method. • Polynomial method. • CORDIC method.	0.5

	•	
3.2	**Topic 01.3. Digital methods of** signal generation **from LCM [22—49]:** • Control of GC parameters in the 2nd order LRRPC method. • Control of GC parameters in the PCS method. • Control of GC parameters in the polynomial method. • Controlling GC parameters in the CORDIC method.	0.5
3.3	**Topic 01.4. Digital methods of generating** noise-like signals [50—65]: • Congruent method. • XORSHIFT method. • MWC and SWC methods. • Ziggurat method. • Mersenne method. • Fibonacci method. • ZRA transformation. • ACF estimation. • PDF estimation. • PSD estimation. • Cryptographic methods and cryptographic resistance of PVP. • Randomness tests.	0.5
3.4	**Topic 01.5. Digital methods for generating** arbitrary waveform signals [48—49]: • LookUp table settings in the PCS method. • Linear interpolation of tabular data. • Spline interpolation of tabular data.	0.5
	TOTAL	**4.00**
	Section 2. Signal encoding during conversion and transmission in baseband	
4.1	**Topic 02.1. Concepts of** data and signal encoding **[70—100]:** • General interpretation of code and coding. • Code and coding in data processing theory and data representation. • Code and coding in computer programming and hardware device control. • Code and coding in the theory of lossy and lossless data compression. • Code and coding in cryptography. • Code and coding in data transmission theory. • Code and coding in mathematics and computer science.	1.0
4.2	**Topic 02.2. Encoding of analog signals** during their conversion and formatting [70—**100]:** • linear binary code, binary-complement code, binary-decimal code, and 7-segment code in signal ADCs. • Encoding according to the A- and μ-laws in speech ADCs. • PCM, DPCM, APCM, ADPCM, DM. • Pulse Modulation. PAM, PWM, PDM, PPM. • Spectral signal coding, subband coding, adaptive transform coding. • Source coding.	1.0
5.1	**Topic 02.3. Coding of digital signals** during their transmission in baseband (line **coding) [70—100]:** • Types of linear codes. Polar, Uni-polar, Bipolar. • Basic pulse shapes. NRZ, RZ, Manchester Line Code. • Phase encoded. • Multilevel binary. • Duobinary Signaling, Coding and Decoding.	1.0
5.2	**Topic 02.4. Data encoding during** modulation (binary encoding & symbol **mapping) [70—100]:** • Encoding binary data using Gray code when mapping it to a phase constellation. • Mapping symbols onto a phase constellation in BPSK, QPSK, M-PSK, 16-QAM, 32-QAM.	1.0
	TOTAL	**4.00**
	Section 3. Analog methods of signal modulation in baseband and passband	
6.1	**Topic 03.1. Amplitude modulation (**AM) of analog signals in passband. AM-DSB-FC, **AM-DSB-SC, AM-SSB-FC, AM-SSB-SC [1, §7.1—§7.8, pp. 334—389]:** ▪ Tonal AM (DSB-FC). Representation of signals in the time and frequency domains. Vector diagrams [1, §7.1, pp. 336–345]. ▪ Energy characteristics of AM oscillations [1, §7.2, pp. 345–349]. ▪ AM oscillations with an arbitrary signal [1, §7.3, pp. 349–357]. ▪ Quadratic modulator [1, §7.3, pp. 357–358]. ▪ Quadratic detector [1, §7.3, pp. 358–359]. ▪ Balance (double sideband) modulation with carrier suppression (DSB-SC) [1, §7.4, pp. 359–361]. ▪ Balanced modulator [1, §7.4, pp. 361–361]. ▪ Synchronous (coherent) detection of oscillations with double sideband modulation [1, §7.4, pp. 361–367]. ▪ Quadrature amplitude modulation (QAM) [1, §7.5, pp. 367–369].	1.0

	▪ Single-sideband modulation (SSB) [1, §7.6, pp. 369–381].
	▪ Description of SSB signals in the frequency domain [1, §7.6, pp. 370–372].
	▪ Description of single-sideband modulated signals in the time domain [1, §7.6, pp. 372–379].
	  ○ Method of generating single-band AM signals based on phase discrimination [1, §7.6, pp. 379–379].
	  ○ Demodulation of single-sideband AM oscillations [1, §7.6, pp. 379–381].
	  ○ Single-sideband AM with incomplete (partial) suppression of the sideband — Vestigial sideband modulation (VSB) [1, §7.7, pp. 381–382].
	  ○ Description of signals with VSB modulation in the frequency domain [1, §7.7, p. 382].
	  ○ Generation of signals with VSB modulation [1, §7.7, pp. 382–386].
	▪ Comparative analysis of signals and systems with amplitude modulation [1, §7.8, pp. 386–389].	

6.2	**Topic 03.2. Angle-modulated** (AM) signals. **Frequency modulation (FM) and phase modulation (PM) of analog signals in passband [1, §8.1–§8.8, pp. 395–481]:**
	▪ Angular modulation: basic concept [1, §8.1, pp. 396–400].
	▪ Representation of signals with tonal angle modulation in the time domain [1, §8.2, pp. 400–404].
	▪ Spectra of signals with tonal angular modulation [1, §8.3, pp. 404–423].
	▪ Generation and detection of signals with angular modulation [1, §8.4, pp. 423–431].
	▪ Angular modulation with a non-harmonic modulating signal [1, §8.5, pp. 431–437].
	▪ Radio pulses with linear frequency modulation (LFM) [1, §8.6, pp. 437–452].
	▪ Radio pulse with LFM, its characteristics and properties [1, §8.6, pp. 437–439].
	  ○ Spectrum of a radio pulse with linear frequency modulation [1, §8.6, pp. 439–448].
	  ○ ACF of a radio pulse with LFM [1, §8.6, pp. 448–452].
	  ○ Radio signals with phase modulation (FMN) [1, §8.7, pp. 452–475].
	  ○ ACF of radio pulses with phase modulation [1, §8.7, pp. 454–455].
	▪ ACF of Barker's FM signals [1, §8.7, pp. 455–457].
	▪ Spectra of FM signals of Barker [1, §8.7, pp. 457–561].
	  ○ Generation of Barker FM signals [1, §8.7, pp. 461–461].
	  ○ Binary pseudorandom sequence [1, §8.7, pp. 461–465].
	  ○ Signals with phase modulation by binary pseudorandom sequences [1, §8.7, pp. 465–466].
	  ○ ACF of signals manipulated by M-sequences [1, §8.7, pp. 466–470].
	  ○ Spectra of signals manipulated by M-sequences [1, §8.7, pp. 470–475].
		1.0

	TOTAL	**2.00**
	Section 4. Digital methods of signal modulation in baseband and passband	
7.1	**Topic 04.1. Amplitude modulation of digital** signals in baseband [102–121]. ▪ Amplitude manipulation (ASK), minimum required passband width, ▪ Quadrature amplitude modulation (QAM).	1.0
7.2	**Topic 04.2. Frequency modulation of digital** signals in baseband [102—121]: ▪ Frequency modulation (FSK), hard FSK and soft FSK, ▪ Binary FSK (BFSK), minimum required bandwidth, modulation index and FSK orthogonality conditions, ▪ M-position frequency shift keying (M-FSK), ▪ Minimum shift keying (MSK or MFSK), fast frequency shift keying (FFSK), ▪ Gaussian filter minimum frequency shift keying (GFSK).	1.0

8.1	**Topic 04.3. Phase modulation of digital** signals in baseband [102—121]:
	▪ Phase shift keying (PSK), its types and characteristics,
	  ○ Binary phase shift keying (BPSK, 2-PSK), minimum required bandwidth,
	  ○ Quadrature phase shift keying (4-PSK, QPSK), transmitter and receiver structure for QPSK, bit error probability, time and spectral characteristics, minimum required passband width,
	  ○ .... Differential quadrature phase shift keying (π/4-DQPSK),
	  ○ Offset QPSK (OQPSK),
	  ○ Square quadrature phase shift keying (SQPSK),
	  ○ Shaped offset QPSK (SOQPSK),
	  ○ .... Dual polarization quadrature phase shift keying (DPQPSK),
	  ○ Higher-order PSK, M-position phase shift keying (M-PSK), Bit error rate (BER) in PSK,
	• Differential phase shift keying (DPSK), its types and characteristics,
	  ○ Differential coding in DPSK,
	  ○ Differentially-encoded BPSK, or BPSK with differential encoding (DBPSK),
	  ○ Symmetric differential phase shift keying (SDPSK),
	  ○ Differentially encoded QPSK (DQPSK),
	  ○ Symmetric differential quadrature phase shift keying (SDQPSK),
	  ○ ....Probability of bit error for DPSK,
	  ○ DPSK demodulation.
		1.0

8.2	**Topic 04.4. Continuous phase modulation of digital** signals in baseband [102—121]: ▪ Continuous phase frequency shift keying (CPFSK), ▪ Continuous phase modulation (CPM). ▪ Minimum shift keying (MSK), ▪ Gaussian filter minimum shift keying (GFSK).	0.5
8.3	**Topic 04.5. Lattice coded** modulation of digital signals in baseband [102—**121]:** ▪ Phase manipulation using coded lattice (PSKTCM), ▪ General QAM modulation using binary data coding with a convolutional encoder (General QAMTCM), ▪ QAM modulation using rectangular QAM constellation and convolutional encoding of binary data (Rectangular QAMTCM).	0.5
	TOTAL	**4.00**
	Chapter 5. Access methods and wideband modulation	
9.1	**Topic 05.1.** Frequency Division Multiple **Access (FDMA) [122–138]:** ▪ Frequency Division Multiple Access (FDMA) [5, §11.1.1, pp. 657–665, §11.4.1–11.4.3, 690–698], [6, §15-1, p. 842, §15-4, pp. 862–872] ▪ Time division multiple access (TDMA) [5, §11.1.2–11.1.4, pp. 665–672, §11.4.4, 704–708], [6, §15-1, p. 842] ▪ Code Division Multiple Access (CDMA) [5, §11.1.5, pp. 672–674, §12.7, 769–771, §12.8, 776–794], [6, §15-2, p. 843, §15-3, pp. 849–862] o The basic concept of CDMA, o Stages of CDMA modulation, o Codes used in CDMA, o Synchronous CDMA (CDM, code division multiplexing), o Asynchronous CDMA, Advantages of asynchronous CDMA over other methods, o Shared CDMA, ▪ Orthogonal Frequency Division Multiple Access (OFDMA).	1.0
9.2	**Topic 05.2. Data modulation** using the OFDM method [122—138]: ▪ Comparison of the efficiency of single-carrier and multi-carrier systems. ▪ Idealized model of a system with OFDM modulation. ▪ OFDM modulation in the transmitter. ▪ OFDM demodulation in the receiver. ▪ DVB-T transmission system.	1.0
	TOTAL	**2.00**
	TOTAL	18.00

Practical classes

No	***Name of the lesson topic and list of main questions*** (list of teaching aids, references to literature, and assignments for independent study)	***Hours***
1	PR-00. Investigation of the main characteristics of harmonic oscillation	1.
	PR-01. Generating harmonic oscillations using the CORDIC method	1.0
2	PR-02. Generation of harmonic oscillations using the 2nd order LRRzPK method	2.0
3	PR-03. Generation of harmonic oscillation using the SIN function approximation method	2.0
4	PR-04. Generation of harmonic oscillation using the DDS method	2.0
5	PR-05.1. Generation of ECS using the DDS method	2.0
6	PR-05.2. Generation of ECS using the table interpolation method	2.0
7	PR-06. Generation of SPS from URAND (Uniformly Distributed Random Data) based on the congruent method	1.
	PR-07. Generation of RNG using NRAND (Normal Distributed Random Data) based on the congruent method	1.0
8	PR-08. Generation of pseudorandom data from uniformly distributed random data (URAND) using the Mersenne Twister method	1.0
	PR-09. Generating pseudorandom numbers from uniformly distributed random data (URAND) using the XORSHIFT method	1.0
9	PR-10. Generating oscillations from LCM using the CORDIC method	1.0
	PR-11. Generating oscillations from LCM using the DDS method	1.0
	TOTAL	**18.00**

Laboratory classes (computer workshops)

No	*Name of the topic*	*Hours*
1	Synthesis and demodulation of DTMF signals 1.1. Synthesis of DTMF signals (Task 1 for LR No. 1) 1.2. Demodulation of DTMF signals (Task 2 for LR No. 1)	4.5
2	Synthesis and demodulation of QAM signals 2.1. QAM signal synthesis (Task 1 to LR No. 2) 2.2. Demodulation of a QAM signal (Task 2 for LR No. 2)	4.5
3	Synthesis and demodulation of OFDM signals using BPSK, QPSK, PSK-16, and PSK-256 3.1. Synthesis of an OFDM signal (Task 1 for LR No. 3) 3.2. Demodulation of an OFDM signal (Task 2 for LR No. 3)	4.5
4	Data transmission using OFDM technology in the DVB-T 2k system 4.1. Data transmission using OFDM technology in the DVB-T 2k system (Task 1 for LR No. 4)	4.5
	TOTAL	**18.00**

Modular and thematic tests

Modular and thematic control works are performed in the form of tests (which ensures objective assessment of knowledge) and downloads (which ensures subjective assessment of skills) in the *Moodle* LMS (*dtsp.kiev.ua*) [33]. When performing MT, it is recommended to use materials [28, 29, 30].

No	*Name of the task topic*
1	**Modular Test (MT)** The work is performed in the form of independent study of materials and development of test questions on any topic of the discipline. Example for topic 1: Topic-01. Signal Generator Terminology and Specifications - 01. Signal Generator Terminology and Specifications - NI, 2022-10, 10p - 03. Key Characteristics of Signal Generators and Modulation Methods. Pocket Guide - R&S, 2022-11, 117p - 04. Modulation and Signal Generation with R&S Signal Generators. Educational Note - R&S, 2016-08, 124p - 05. Signal Generator Fundamentals - Tektronix, 2009-03, 54p - 08. The Essential Signal Generator Guide. Building a Solid Foundation in RF. Part 1 - Keysight, 2022-06, 28p - 21. Walt Kester. High Speed DACs & DDS systems - 22. Fundamentals of Direct Digital Synthesis (DDS) - ADI, MT-085. 2010-08, 9p Task Systematize the material studied on the relevant (self-selected) topic of the discipline and compose 5 test questions similar to the test questions in the tests after topic 1 (see Test 2).
2	**Thematic test (TT)** Thematic test on the topic "Jitter and its measurement"

3	**Thematic test (TT)** **Thematic test on the topic "QPSK modulation"**

6. Independent work of the student

Students must prepare in advance for lectures, practical and laboratory classes (computer workshops). Before lectures, it is necessary to review the theoretical material provided in previous lectures. Before practical and laboratory classes (computer workshops), it is necessary to review the relevant theoretical material.

It is mandatory to complete individual assignments for computer workshops, which must be completed before the next laboratory class. To prepare for individual assignments, students should use the recommended literature and lecture notes.

To better consolidate the theoretical material, students must complete thematic and modular tests (in *the Moodle* LMS), the preparation for which requires careful review of the theoretical material from the relevant lectures during independent study hours.

Policy and control

7.Policy of the academic discipline (educational component)

Class attendance

Attendance at lectures, practical classes, and laboratory classes is mandatory in accordance with the Regulations on the Organization of the Educational Process at Igor Sikorsky KPI. In case of illness, students are required to submit a duly completed certificate of treatment from the institution where they were treated. In other cases (e.g., family circumstances), the issue is resolved on an individual basis with the instructor. Material from classes that were missed for one reason or another must be mastered independently. To assist students, the SDN dtsp.kiev.ua contains links to video recordings of all lectures.

Missed tests

Submission of the results of simulation work, TCW and MT is mandatory. Late submission will result in a zero grade. In case of late submission for valid reasons (e.g., illness) confirmed by relevant documents, the student has the opportunity to take the test at another time agreed with the teacher without a reduction in grade. For the purpose of self-improvement and improvement of one's own results, it is allowed to retake the TCW and MT.

A missed exam will not be counted regardless of the reasons for the absence; in this case, the student will receive a "no show" mark and must take the exam during an additional session.

Announcement of test results

The results of independent work are entered into the Moodle LMS and announced to each student individually in person or remotely, accompanied by assessment sheets (in the Moodle LMS) in which students can see their grades according to specific criteria, as well as the main mistakes and comments on them.

The results of the written exam are indicated on the forms for the written exam (tasks performed by students) with an indication of all errors, correct or incorrect answers, as well as comments, remarks, etc. The exam can be conducted in the form of tests and tasks using the capabilities of the Moodle LMS.

Academic integrity

The policy and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute." For more details, see: https://kpi.ua/code.

Standards of ethical behavior

The standards of ethical conduct for students and employees are defined in Section 2 of the Code of Honor

of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". For more information, please visit: https://kpi.ua/code.

Procedure for appealing the results of control measures

Students have the opportunity to ask any question regarding the procedure for conducting and/or evaluating tests and expect that it will be considered in accordance with predetermined procedures.

Students have the right to appeal the results of control measures, but they must provide a reasoned explanation of which criteria they disagree with according to the assessment sheet and/or comments.

8.Types of assessment and learning outcomes rating system for assessing (RSA)

1. Task completion and student ratings are recorded in the Moodle DTSP.KIEV.UA learning management system. From the first day of the course, students create personal profiles in the learning management system and gain access to all course materials, including the rules of the rating system and their own grade book.

2. The student's rating for the credit module is calculated on a 100-point scale (100% success rate)

$$R_m = R_s + R_e = 100;$$
$$R_{smax} = 60; \; R_{emax} = 40.$$

The starting rating R_s (semester component) consists of points that the student receives for:

- completing laboratory (simulation) tasks (6 assignments);
- completing modular tests (4 assignments);
- completion of thematic tests (1 assignment for each topic);
- completing computational and graphical assignments (1 assignment);
- additional activities.

3. Completion, formatting, and defense of reports on the completion of laboratory work (LR) (computer workshops), which provide the following performance rating points:

completion of laboratory work (computer workshop)	40%
formatting of the report in accordance with the requirements	20
report formatting with violations	0...10
complete answer (at least 90% of the required information) during the defense of the LR in the current or next laboratory class	40
incomplete answer (at least 60% of the required information and some errors) or untimely defense of the LR	20
answer with significant errors	10
unsatisfactory answer	0

Contribution of points for six LR to the semester component of the rating– 25%.

Completion of thematic and modular control works (TCW and MCW) with manual assessment:

complete answer (at least 90% of the required information)	95…100
sufficiently complete answer (at least 75% of the required information or minor inaccuracies)	75–94
incomplete answer (at least 60% of the required information and some errors)	60...74
unsatisfactory answer	0...59

Contribution to the semester component of the rating points for TCW and MT (theoretical classes)– 35%

Contribution to the semester component of the rating points for tests and homework (practical classes)– 25%

4. The condition for *a* positive *first assessment* is to obtain a current rating of at least 60% (60 points) (provided that all TCR and other planned tasks are completed by the time of assessment). The condition for *a* positive *second assessment* is to obtain a current rating of at least 60% (60 points) (provided that all MTs and other planned tasks are completed by the time of the assessment).

5. The condition for admission to the exam is the completion of all laboratory work (computer practicals), calculation work, and a starting rating of at least 60% (60 points).

6. During the exam, students complete a written test. Each task contains two theoretical questions and one calculation task. The list of exam tasks is available on the MOODLE website for the discipline.

Each theoretical question is worth 30% of the maximum exam score, and the calculation task is worth 40% of the final grade.

As a result

R_e= 2× 30 + 40 = 100% of the final grade = 40 points (exam component).

7. The sum of the starting points and the points for the exam test is converted to an exam grade according to the table:

Points	Grade
100…95	Excellent
94	Very good
84	Good
74…65	Satisfactory
64	Sufficient
Less than 60	Unsatisfactory
There are uncredited modeling tasks or uncredited module test	Not admitted

Work program for the academic discipline (syllabus):

Completed Senior Lecturer, RED Oleg Pavlov,
Associate Professor of the RED Elena Guseva

Approved by the RED (Minutes No. 06/2024 dated June 26, 2024).

Approved by the REF Methodological Commission (Minutes No. 06/2024 dated 28.06.2024).