Національний технічний університет України «КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ імені ІГОРЯ СІКОРСЬКОГО»

Emblem of the department (if available)

Computer Engineering department

Computer circuitry

Syllabus

Details of the academic discipline

Level of higher education	***First (bachelor's)***
Branch of knowledge	*12 Information Technologies*
Specialty	*123 Computer engineering*
Educational program	*Computer Systems and Networks*
Discipline status	*Normative*
Form of education	*Full-time/ extramural*
Year of training, semester	*3rd year, autumn semester*
Scope of the discipline	*4 credits, 120 hours*
Semester control/ control measures	*Examination/calendar control*
Timetable	*According to the schedule for the fall semester of the current academic year at* rozklad.kpi.ua
Language of teaching	*Ukrainian*
Information about the course leader / teachers	*Lectures: associate Professor CE dept., Candidate. of Tech. Science, Associate Professor* *Verba Aleksandr, olverba@gmail.com*, professor, Ph.D. Klymenko Iryna Anatolyivna, iklirуna@gmail.com Laboratory : *associate Professor CE dept., Candidate. of Tech. Science, Associate Professor* *Verba Aleksandr, olverba@gmail.com*
Placement of the course	https://comsys.kpi.ua

Program of educational discipline

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

The discipline "Computer circuit engineering" is a normative, professionally-oriented discipline for the training of bachelors from the educational direction of specialists in the specialty "Computer engineering" and is of fundamental importance for the training of specialists at the educational levels of a bachelor's specialist and a master's degree both within the scope of "Computer engineering" , as well as a number of related specialties, areas related to computer technology, digital instrumentation, digital television and radio communication, information and measurement technology, telecommunications systems and other "electronic" fields of human activity. As a scientific and technical direction, "Computer circuit engineering" is based on the latest manufacturing technologies of various electronic components used in digital, analog-digital and analog technology. At the same time, new schematic and functional solutions for the construction of *hardware blocks of computer systems and networks, their application in a qualitatively new computer architecture and using modern methods and systems of design automation .*

The course "Computer circuit engineering" is a special basic course in the general scheme of training students in the direction of training 123 "Computer engineering".

***The aim of the course** is to acquaint students with the modern principles of organization, construction , design and operation of circuit-technical units and devices of computer systems .*

***The subject is mathematical, algorithmic and hardware methods of building schematic components of modern computers, their modeling, research of the main characteristics and the optimal choice of implementation methods in the** Quartus design automation system II and implementation on the FPGA crystal of Altera board DE 2 Board (Cyclon II) .*

As a result of studying the course, each student should:

1. To know the main functions, structure and basics of the functioning of computer systems ;

2. Know the methods of synthesis of typical nodes, blocks, and devices of computer systems;

3. To learn approaches to the development of nodes, blocks and devices on the structural , functional levels and the level of principle schemes in the given element base.

4. Understand the basic principles of building computer systems;

5. Know the structure and functioning of typical nodes , blocks and devices computer systems;

6. To know the modern elementary base of digital technology - software logic integrated circuits FPGA , integrated memory circuits, etc.;

7 . Be able to develop structural, functional and principle diagrams of nodes, blocks, devices of computer systems.

8. To solve the applied problems of designing typical nodes, blocks and devices of computers and researching their characteristics in the Quartus II design automation system and its implementation on the FPGA crystal of the company Altera DE2 Board (Cyclon II) .

*credit module provides **the following competencies and program results of the** educational and professional program of the first (bachelor) level of higher education (OPP):*

GC1 - Ability to abstract thinking, analysis and synthesis; GC2 - Ability to learn and master modern knowledge; GC3 - Ability to apply knowledge in practical situations; GC7 - Ability to identify, pose and solve problems; PC5 - Ability to use design automation tools and systems to develop components of computer systems and networks, Internet applications, cyber-physical systems, etc. PC11 - Ability to formalize the obtained work results in the form of presentations, scientific and technical reports; PC14 - Ability to design systems and their components taking into account all aspects of their life cycle and task, configuration, operation, maintenance and disposal; PC16 - Ability to design, implement and maintain high-performance parallel and distributed computer systems and their components using FPGA modules and automated design systems ;

***KNOWLEDGE :** modern element base of computer circuitry; modern automated design systems; circuit-technical basics of modern computers; principles of construction of typical nodes, blocks, computer devices; means of assessing their quality; methods of their design in various systems of elements, including large integrated circuits; PLO1 - Know and understand the scientific provisions underlying the functioning of computer tools, systems and networks; PLO3 - Know the latest technologies in the field of computer engineering;*

***SKILLS:** PLO7 - To be able to solve problems of analysis and synthesis of means characteristic of the specialty; PLO9 - To be able to apply knowledge of technical characteristics, design features, purpose and rules of operation of software and technical means of computer systems and networks to solve technical problems of the specialty; PLO13 - To be able to identify, classify and describe the operation of computer systems and their components; PLO22 - Perform parameter calculations of individual blocks of computers, computer systems, computer networks .*

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

The course "Computer circuit engineering" (PM19) belongs to the normative disciplines of the specialty "123 - Computer engineering". The study of the discipline should be preceded by the study of such disciplines as ZM12 "Theory of electric circuits and signals", PM1.1 "Computer logic" . Part 1 ", PM1.2 "Computer logic. Part 2 ", ZM14 "Computer electronics" and PM6.1 " Architecture computers . _ Part 1 ". The list of disciplines that, among other things, are based on the results of training in this discipline include software 6.2 " Architecture computers . _ Part 2 » , PM6.3 « Architecture computers . _ Part 3 , PM11 "Computer systems" , PM12 " Protection of information in computer systems and networks ", PM17 " Architecture computers . _ Course work " and PM21 "Diploma design " .

3. Credit module content

Topic 1. Computer and chemical engineering. Stages of development. Classification of integrated circuits.
Quartus design automation system II . Creating a project using the schematic editor.
Topic 3. Functional elements of computer circuitry. Basic logical elements, their characteristics.
Topic 4. Combinational functional devices. Adders. Decryptors. Encryptors. Code converters. Multiplexers. Demultiplexers. Comparators. Control schemes.
Topic 5. Computer devices on triggers. Registers. Counters.
Topic 6. Analog-digital, digital-analog converters.
Topic 7. Firmware control devices.
Topic 8. Arithmetic and logical devices.
Topic 9. Semiconductor memory devices (ZP). Static RAM (SRAM) . Dynamic RAM (DRAM). Permanent and reprogrammable ZP. Cache memory. Associative memory.
Topic 10. Software logic integrated circuits (PLC). PLM, BMK, FPGA .
Verilog hardware description language . Creating a project in CAD Quartus II and implementation on an FPGA chip Cyclone II .

4. Educational materials and resources

Basic:

1. Computer circuit engineering: [Electronic resource]: teaching. manual for students of the educational program "Computer systems and networks" in specialty 123 "Computer engineering" / O. A. Verba, V. I. Zhabin, I. A. Klymenko, V. V. Tkachenko; KPI named after Igor Sikorsky. – Electronic text data (1 file: 8.64 MB). – Kyiv: KPI named after Igor Sikorskyi, 2019. – 110 p. https://ela.kpi.ua/handle/123456789/29747

2. Computer circuit technology: a textbook / O. D. Azarov, V. A. Garnaga, Y. M. Klyatchenko, V. P. Tarasenko - Vinnytsia: VNTU, 2018. - 230 p. ISBN 978-966-641-736-0
3. Babich M.P., Zhukov I.A. Computer circuit engineering: A study guide. - K.: "MK-Press", 2004. – 412 p.

4. Architecture of computer systems: laboratory practice [Electronic resource]: study guide for students. specialty 126 "Information systems and technologies" / E. O. Batrak ; KPI named after Igor Sikorsky. – Electronic text data (1 file: 12.3 MB). – Kyiv: KPI named after Igor Sikorskyi, 2020. – 110p.

Additional:

5. Matvienko M.P., Rozan V.P. Computer circuitry. Tutorial. - Kyiv: Lira Publishing House - K, 2016. - 192 p.
6. DSTU 3212-95. Microcircuits are integrated. Classification and system of conventional designations.

Informational _ resources :

7. Quartus II Introduction Using Schematic Design ftp://ftp.altera.com/up/pub/Tutorials/DE2/Digital_Logic/tut_quartus_intro_schem.pdf

8. Computer circuitry. https://www.college-chnu.cv.ua/images/Books/Komp_N/Osn_Sh.pdf

Equipment needed for classes

Lecture classes are held in a classroom equipped with a projector, laboratory classes are held in a computer laboratory.

Educational content

5. Methods of mastering an educational discipline (educational component) (Full-time form)

The structure of the credit module

Names of sections, topics	hours			
	In total	Medicine	Lab.	IWS
1	2	3	4	5
Topic 1. Computer and chemical engineering. Stages of development. Classification of integrated circuits.	5	2		3
Quartus design automation system II . Creating a project using the schematic editor.	16	4	4	8
Topic 3. Functional elements of computer circuitry. Basic logical elements, their characteristics.	5	2		3
Topic 4. Combinational functional devices. Adders. Decryptors. Encryptors. Code converters. Multiplexers. Demultiplexers. Comparators. Control schemes.	16	4	4	8
Topic 5. Computer devices on triggers. Registers. Counters.	14	4	2	8
Topic 6. Analog-digital, digital-analog converters.	5	2		3
Topic 7. Firmware control devices	5	2		3

Topic 8. Arithmetic and logical devices.	14	2	4	8
Topic 9. Semiconductor memory devices (ZP). Static RAM (SRAM) . Dynamic RAM (DRAM). Permanent and reprogrammable ZP. Cache memory. Associative memory.	14	6		8
Topic 10. Software logic integrated circuits (PLC). PLM, BMK, FPGA .	5	2		3
Topic 11. Verilog hardware description language HDL .	9	4		5
Quartus CAD project II on the FPGA chip Cyclone II 2 C 35.	12	2	4	6
Total per semester	120	36	18	66

Lectures (Full-time)

1	**Lecture 1.** *Topic 1. Computer and chemical engineering. Stages of development. Classification of integrated circuits. (Classifications of digital computer elements. Integrated microcircuits (IMS). IMS classifications. Standard IMS. Specialized IMS. IMS parameters. Requirements for IMS series.)* Literature [3, p. 60-90; 6, p. 1-9; 8. p. 2-5]. Task on IWS: *System of conditional designations of digital schemes. Designation, classification and types of IMS cases.* Literature [6, p. 1-9; 8. p. 2-5].
2	**Lecture 2 - 3.** Topic 2. *Quartus design automation system II . Creating a project using the schematic editor. (Quartus® II software environment of the company Altera®, stages of the standard design process in Quartus II CAD , project creation, project input in schematic mode, project synthesis, work in the graphic editor, development of functional blocks, placement and tracing of the project, analysis of time delays, modeling project, microcircuit programming, in-chip project debugging, wizard for creating a new project New Project Wizard).* Literature [1, p. 7-32;]. CSC task: *Setting up the pages of the New Project Wizard. Development of functional blocks of combinational circuits.* Literature [1, p. 7-32;].
3	**Lecture 4.** *Topic 3. About dreams of semiconductor circuitry logical elements and their components (Functional elements of computer circuitry. Basic logical elements, circuit-technological types, basic characteristics of logical elements , TTL elements, CMOS logic elements).* Literature [2, p. 22-47]. Tasks on IWS: *logical elements on bipolar and field transistors* . Literature [2, p. 22-47].
4	**Lecture 5-6.** *Topic 4. Combinational functional devices. Adders. Decryptors. Encryptors. Code converters. Multiplexers. Demultiplexers. Comparators. Control schemes.* Literature [2, p. 156-176]. Tasks on IWS: *design and research of adders.* Literature [2, p. 156-176].
5	**Lecture 7-8.** *Topic 5. Computer devices on triggers. Registers. Counters.* Literature [2, p. 104-118]. Tasks on IWS: *Asynchronous and synchronous trigger devices (TP) with static in the board .* Literature [2, p. 104-118].
6	**Lecture 9.** *Topic 6. Analog-digital, digital-analog converters.* Literature [3, p. 179-190]. Task on IWS: *quantization of analog signals.* Literature [3, p. 179-190]

7	**Lecture 10.** *Topic 7. Firmware control devices (principle of microprogram control, program, command, microprogram, microcommand, microcommand format, device structure.* Literature [3, p. 252-260]. Tasks on the IWS: *organizing the operation of the device firmware control* . Literature [3, p. 252-260]
9	**Lecture 11.** *Topic 8. Arithmetic and logical devices (ALP).* Tasks on IWS: *methods of data processing in ALP, matrix multipliers.* Literature [2, p. 177-183].
10	**Lecture 12-14.** *Topic 9. Semiconductor memory devices (ZP). Static RAM (SRAM). Dynamic RAM (DRAM). Permanent and reprogrammable ZP. Cache memory. Associative memory. FLASH memory.* Literature [2, p. 183-201]. Task on IWS: *classification of memory devices.* Literature [2, p. 183-201].
11	**Lecture 15.** *Topic 10. Software logic integrated circuits (PLC). PLM, BMK, FPGA .* [2, p. 183-201]. Tasks on IWS: *structural organization of FPLIS .* Literature [2, p. 183-201].
12	**Lecture 16-17.** *Topic 11. Verilog hardware description language HDL (lexical elements, data, operations and expressions, delay processes, alphabet, description of nodes, interface, primitives, D -trigger, RS -trigger-latch, Verilog model).* Literature [4, p. 4-25]. Tasks on IWS *: Basics of working in Quartus with the SystemVerilog language HDL .* Literature [4, p. 4-25].
thirteen	**Lecture 18.** Topic 12. Implementation of the *Quartus CAD project II on the FPGA chip Cyclone II 2 C 35.* Literature [1 , p. 76 - 98]. Task on IWS: *uploading the configuration file to FPGA on board DE 2 Altera* . Literature [1 , p. 76 - 98].

Laboratory classes (Face-to-face)

The purpose of the laboratory work is to acquire skills and practical application of methods of synthesis and design of nodes, blocks and computer devices using CAD and implementation of projects on the FPGA crystal . Laboratory classes are performed on computers using CAD QUARTUS II and subsequent FPGA programming on an Altera board DE 2 .

No. z/p	Name of laboratory work (computer workshop)	Number of aud. hours
1	*Laboratory work #1. STUDY OF DESIGN AUTOMATION SYSTEM QUARTUS II. PROJECT CREATION .*	*4*
2	*Laboratory work #2. DEVELOPMENT OF THE COMBINATION ADDER MODULE .*	*2*
3	*Laboratory work No. 3. PROJECT COMPILATION IN CAD QUARTUS II. ANALYSIS OF COMPILATION RESULTS .*	*2*
4	*Laboratory work No. 4 . SIMULATION IN CAD QUARTUS II. MODELING.*	*2*
5	*Laboratory work #5. DEVELOPMENT OF MODULES FOR PERFORMING ARITHMETIC OPERATIONS IN CAD QUARTUS II. PROGRAMMING PLIS IN CAD QUARTUS II.*	*4*
6	*Laboratory work #6. DEVELOPMENT OF MODULES OF ARITHMETIC AND LOGIC BLOCKS IN CAD QUARTUS II. OUTPUT OF OPERATIONS RESULTS ON SEVEN-SEGMENT INDICATORS.*	*4*
	Together:	*18*

6. Independent work of students (Full-time)

Students' independent work includes: *preparation for lectures; preparation for laboratory classes; preparation for the exam.*

No s/p	*Name topics, that is carried out independently processing*	*Number hours of IWS*
1	*Topic 1. Computer and chemical engineering. Stages of development. Classification of integrated circuits.*	3
2	*Quartus design automation system II . Creating a project using the schematic editor.*	8
3	*Topic 3. Functional elements of computer circuitry. Basic logical elements, their characteristics.*	3
4	*Topic 4. Combinational functional devices. Adders. Decryptors. Encryptors. Code converters. Multiplexers. Demultiplexers. Comparators. Control schemes.*	8
5	*Topic 5. Computer devices on triggers. Registers. Counters.*	8
6	*Topic 6. Analog-digital, digital-analog converters.*	3
7	*Topic 7. Firmware control devices*	3
8	*Topic 8. Arithmetic and logical devices.*	8
9	*Topic 9. Semiconductor memory devices (ZP). Static RAM (SRAM) . Dynamic RAM (DRAM). Permanent and reprogrammable ZP. Cache memory. Associative memory.*	8
10	*Topic 10. Software logic integrated circuits (PLC). PLM, BMK, FPGA .*	3
11	*Topic 11. Verilog hardware description language HDL .*	5
12	*Quartus CAD project II on the FPGA chip Cyclone II 2 C 35.*	6
	Together:	66

Policy and control

7. Policy of academic discipline (educational component)

During credit module classes, students must adhere to certain disciplinary rules:

- *it is forbidden to be late for classes;*
- *at the entrance of the teacher, as a sign of greeting, persons studying at KPI named after Igor Sikorsky should stand up;*
- *extraneous conversations or other noise that interferes with classes are not allowed;*
- *leaving the classroom during the lesson is allowed only with the teacher's permission.*
- *the use of mobile phones and other technical means is not allowed without the teacher's permission.*

Types of control and rating system for evaluating learning outcomes (RSE)

8.1. Kinds control with educational disciplines include:

Laboratory work:
Scheduled independent implementation six laboratory works . Topics laboratory works agreed upon in times and by content with topics lectures

Current control **:**
It is foreseen carrying out calculation of each laboratory work _

*The student's semester rating from the credit module is calculated based on a 100-point scale. The rating consists of the points that the student receives for completing 6 R_L **laboratory works and the** R_E exam .*

8.2. The maximum number of points for each laboratory work is 10, i.e. R_L=60 (10·6=60). Points are awarded for:

- timeliness of preparation of the protocol for the laboratory session, completeness of the theoretical task: 0-2 points;
- the correctness of the functioning of the developed models on the software emulator (complex of programs for debugging models): 0-5 points,
- protection of the results obtained in the work, answers to the teacher's theoretical questions, completeness of the work protocol: 0-3 points.

8.3. The maximum number of points for the exam is RE = 40.

The examination ticket contains 4 tasks (one theoretical and three practical) on the subject of lectures and laboratory work performed during the semester. Each question is evaluated from 0 to 10 points.

Evaluation criteria for each question at four levels:

- correct and meaningful answer - 9-10 points;
- correct answer, incomplete explanations - 6-8 points;
- the answer contains errors - 3-5 points;
- there is no answer or the answer is incorrect - 0 points.

8.4. Calendar certification of students (for 8 and 14 weeks of semesters) in the discipline is carried out according to the value of the student's current rating at the time of certification. If the value of this rating is at least 50% of the maximum possible at the time of certification, the student is considered certified. Otherwise, the attestation information is marked as "uncertified".

8.5. A necessary condition for a student's admission to the exam is the completion and defense of all laboratory work with a score of at least 36 (60% of the maximum).

The number of points a student receives per semester is determined by the formula
$R_S = R_L + R_E$.
The maximum number of points per semester does not exceed $\mathbf{R}_C$=100.

8.6. Taking into account the received sum of points, the final grade is determined by the following table.

Determination of the grade on the university scale

$\mathbf{R}_S$	***Rating***
95-100	*Perfectly*
85-94	*Very well*
75-84	*Okay*
65-74	*Satisfactorily*

60-64	*Enough*
R_C< 60	*Unsatisfactorily*
Laboratory work not performed	*Not allowed*

8. Additional information on the discipline (educational component)

The list of questions that are submitted for semester control:

1. What is the essence of the task of analysis and the task of synthesizing a combinational circuit?
2. To characterize the main stages of the synthesis of a combinational circuit based on given logic elements.
3. How is the complexity of combinational schemes evaluated?
4. How to determine the speed of the combinational circuit?
5. What is the peculiarity of the synthesis of combinational circuits with several outputs?
6. What is the basis of the use of a multiplexer to implement the switching function?
7. Draw the generalized structure of the trigger. By what signs are triggers classified?
8. What is the difference between synchronous flip-flops controlled by the level of the clock signal and flip-flops controlled by the edge of the clock signal?
9. How are triggers classified by the method of recording information?
10. Draw the structure of a synchronous trigger made according to the MS scheme with an inverter in the synchronous signal circuit.
11. Draw the structure of a synchronous trigger made according to the MS scheme with prohibitive connections.
12. Draw the structure of a synchronous trigger made on the basis of three bistable circuits on AND-NOT elements, and explain the process of switching the trigger from one state to another.
13. Explain the process of switching from one state to another trigger on OR-NOT elements, made on the basis of three bistable circuits.
14. Formulate the trigger design methodology.
15. What is the difference between synchronous and asynchronous triggers?
16. Explain the difference between informational and asynchronous inputs of a synchronous trigger.
17. Define register.
18. What is the difference between triggers with and without an internal delay?
19. What is the length of the register?
20. Draw a generalized register structure.
21. What registers are called reversible?
22. What does the complexity of the combinational register scheme depend on?
23. By what method is synthesis of registers on which one microoperation is performed in the case of asynchronous and synchronous triggers?
24. What is the difference between the method of designing registers on which several microopera-tions are performed from the method when only one microoperation is performed on the registers?
25. Draw a generalized structure of a synchronous counter.
26. How are counters with a natural number order classified by the method of organization of trans-fer between digits?
27. Give an example of a counter with serial transfer.
28. Compare parallel and through transfer in counters.
29. Name the main time characteristics of counters.
30. Formulate the method of synthesis of synchronous counters with an unnatural order numbers
31. Draw the generalized structure of the ring counter.
32. What does the period of the ring counter depend on?
33 . Appointment of adders. An example of adding one-bit binary numbers.

34 . Explain the difference in the application of a half adder and a one-bit full adder.
35 . Build a circuit for adding two three-bit binary numbers.
36 _ Explain how subtraction of binary numbers is performed.
37 _ What is the peculiarity of the operation of binary-decimal adders?
38 . In which case is there no need to take into account cyclic transfer for adders-subtractors?
39 _ Purpose of storage devices (SD) and their classification.
40 _ List the main parameters of Z P.
41 _ Give examples of different structures of ZP.
42 . Give an example of the structure of the ZP with a single-level organization.
43 . Computer memory based on static Z P.
44 . Computer memory based on dynamic Z P.
45 . Where are static and dynamic Z P used?
46 . Computer memory based on non-volatile memory. How can you classify PZP?
47 _ Give a fragment of the scheme of the mask PZP and explain the principle of recording.
48 . Give a fragment of the diagram of the diode matrix of the reprogrammable PZP and explain the principle of recording.
49 . List the classifications of software logic integrated circuits (PLIS).
50 . What is the difference between software logic matrices (PLM) from software logic matrices (PML)? Give an example of PLM structures and PML.
51 _ What type of FPGA was a continuation of PLM and PML architectures? Give examples of the application of these microcircuits of software logic?
52 . Describe such a device with a software structure as a basic matrix crystal.
53 . Integrated microcircuits with software logic of the FPGA type. Structure, properties and features.

Methodical recommendations for performing laboratory work

The cycle of lectures is complemented by laboratory practice and a significant amount of independent work by students.

Performing laboratory work allows you to expand and consolidate theoretical knowledge of the discipline, master the skills of designing and researching digital circuits. Each laboratory work must be preceded by independent preparation of students, during which they study in detail the description of practical work, relevant sections of the lecture notes and literary sources. In the process of preparation, a report on practical work is drawn up, in which all points of the theoretical task must be reflected, as well as tables, algorithms, schemes, etc. prepared for the experimental part of practical work. Before starting laboratory work, the results of training are checked by the teacher. During such an examination, the student must present the prepared report and answer the control questions. Before the start of the next lesson in the laboratory, the student presents a fully prepared report on the previous work to the teacher. The report should contain brief theoretical information necessary for the performance of the task, answers to control questions, schemes, formulas, algorithms, tables, diagrams, graphs, program code, compiler reports obtained during the performance of the task and in the process of modeling and experimental research of the developed devices, as well as conclusions The student receives credit for the performance of the work after an interview on the topic of the work performed.

The main part of the lecture course, a description of the laboratory works and examples of their implementation are given in textbooks 1-4 from the list of basic literature.

Working program of the academic discipline (syllabus):

Compiled by Oleksandr Andriyovych Verba, associate professor, Ph.D.

Approved by the Department of Computing (Protocol No. 10 dated 05/25/2022).

Agreed by the methodological commission of FIOT (protocol No. 10 dated 09.06.2022).