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Кафедра обчислювальної техніки

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METHODICAL GUIDELINES

for laboratory classes in the course
«Computer architecture» (part 1)
for higher education students of the first (Bachelor's) level
in the educational degree programme «Computer Engineering»
of the field of study 123 «Computer Engineering»
of full-time and part-time forms of study

МЕТОДИЧНІ РЕКОМЕНДАЦІЇ

до лабораторних робіт з навчальної дисципліни
«Архітектура комп'ютерів» (частина 1)
для здобувачів вищої освіти першого (бакалаврського) рівня за освітньо-професійною програмою «Комп'ютерна інженерія» спеціальності **123 «Комп'ютерна інженерія»**
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CONTENT

Introduction

Computer architecture is the science that studies the design and organization of the components of computer systems. It involves the examination of how hardware and software interact to perform tasks, as well as the principles behind structuring these components to achieve high performance, efficiency, and reliability. This discipline covers key elements such as the central processing unit (CPU), memory hierarchy, input/output systems, and data processing units.

The primary goal of computer architecture is to design systems capable of efficiently executing instructions, processing information, and interacting with peripheral devices. It combines theoretical foundations with practical design principles, helping to understand the workings of modern computing systems. Different types of architectures, such as Von Neumann and Harvard architectures, are also analyzed, along with their impact on performance and the selection of optimal design solutions.

As technology advances, the complexity of computer systems grows. With the emergence of multi-core processors, parallel computing, and specialized hardware accelerators, computer architecture is rapidly evolving, requiring specialists not only to understand classical principles but also to adapt to new innovations.

In this course, we will explore the fundamental concepts, design principles, and current trends in computer architecture, equipping you with the knowledge needed to analyze and develop efficient computing systems for various applications.

Вступ

Архітектура комп'ютерів є наукою, яка вивчає проєктування та організацію складових частин комп'ютерних систем. Вона охоплює дослідження взаємодії апаратного і програмного забезпечення для виконання завдань, а також принципи структурування цих компонентів з метою досягнення високої продуктивності, ефективності та надійності. В рамках цієї дисципліни вивчаються ключові елементи, такі як центральний процесор (ЦП), ієрархія пам'яті, системи вводу/виводу та обробки даних.

Основне завдання архітектури комп'ютерів полягає в розробці систем, що здатні ефективно виконувати інструкції, обробляти інформацію та взаємодіяти з периферійними пристроями. Це поєднання теоретичних основ і практичних принципів проєктування, що допомагають зрозуміти принципи роботи сучасних обчислювальних систем. Також аналізуються різні типи архітектур, такі як архітектура фон Неймана і Гарбард, та їх вплив на ефективність і вибір оптимальних рішень при проєктуванні.

З розвитком технологій зростає складність комп'ютерних систем. З появою багатоядерних процесорів, паралельних обчислень та спеціалізованих апаратних акселераторів архітектура комп'ютерів швидко еволюціонує, вимагаючи від фахівців не лише знання класичних принципів, а й уміння адаптуватися до новітніх досягнень.

Вивчаючи цю дисципліну, ми ознайомимося з основними концепціями, принципами проєктування та сучасними тенденціями в архітектурі комп'ютерів, що дасть змогу отримати знання для аналізу та розробки ефективних обчислювальних систем для різноманітних застосувань.

Laboratory work 1

Introduction to Computer Architecture. Key Components of the System Unit

Goals

Study the components of a personal computer and its logical structure. Familiarize with the design and components of a personal computer's motherboard.

Procedure:

1. Familiarize yourself with the theoretical information.
2. Complete the practical tasks.
3. Prepare a report on the laboratory work.
4. Answer the control questions.

Theoretical part

1.1. Overview of a Personal Computer's Structure

A computer is a versatile electronic device designed to automate the processes of collecting, storing, processing, transmitting, and reproducing data.

The components that make up a computing system are collectively referred to as its configuration. The hardware and software aspects of the system are treated separately, which leads to the distinction between hardware and software configurations.

A personal computer is typically divided into two categories: main devices and peripheral devices.

The primary components of the computer include the system unit, which contains the core system devices:

1. *Motherboard* – a large circuit board that hosts or connects all the other system devices.

2. *Central Processing Unit (CPU)* – the "brain" of the computer, responsible for carrying out most computational tasks.

3. *Random Access Memory (RAM)* – used to temporarily store data that is actively being processed.

4. *External Storage* – used for long-term or permanent data storage. This includes devices like the hard drive (HDD), floppy disks, optical disks (CD, DVD, Blu-ray, etc.), magnetic tape drives, and flash storage devices (USB drives).

5. *Video Adapter* – responsible for handling graphical data and displaying it on the monitor.

6. *Sound Card* – used to process and output audio signals to speakers or other audio devices.

Peripheral devices are external devices that connect to the system unit through specialized cables and ports. These include:

1. Input Devices:

Keyboard

Mouse, trackball

Scanner

Graphics tablet

2. Output Devices:

Monitor

Printer

Speakers

Plotter

3. Networking Devices:

Modem

Switch

Network interface card (NIC)

1.2. The motherboard, or mainboard, is the central circuit board to which all the computer's components (such as the processor, graphics card, RAM, etc.) are connected and is housed within the system unit. Its primary role is to integrate these components and facilitate their coordinated functioning.

In terms of appearance, the motherboard of a typical desktop computer is a large circuit board with numerous connectors. The foundation of any modern motherboard is its system logic, commonly known as the chipset. The chipset is a group of microchips that manage the synchronization and communication between the various parts of the computer. Generally, the chipset consists of two main chips, referred to as the "northbridge" and "southbridge."

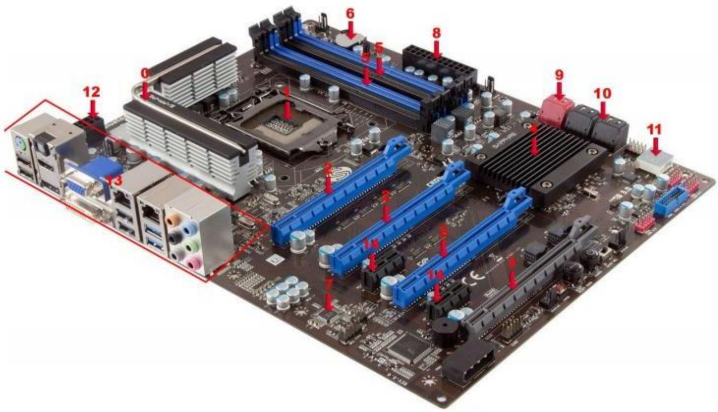

Fig. 1.1. Components of the Motherboard

In figure 1.1 illustrates the layout of the main components of the motherboard, with key elements marked by numbers:

(1) *CPU Socket* – a crucial component where the processor is installed. It is essential that the socket on the motherboard matches the processor socket, as different shapes of connectors will prevent the processor from fitting correctly.

(2) *PCI-Express Slots* – this motherboard has three PCI-Express X16 version 3.0 slots, designed for installing one or more graphics cards. Slot (3) is another PCI-Express x16 slot, but of the older version 2.0. Between the PCI-E X16 slots, slot (14) contains PCI-E X1 slots, which are meant for devices that do not require high bandwidth, such as TV tuners, audio and network cards, and various controllers.

(4) *Chipset* – located under the cooling radiator and marked as number (4), this component contains various controllers that link the motherboard's control section to the processor and other components.

(5) *DDR3 RAM Slots* – these black and blue slots allow memory modules to be installed in dual-channel mode, improving the overall memory performance.

(6) *CMOS Battery* – this battery powers the CMOS chip of the BIOS, ensuring the computer's settings and clock are retained even when the system is turned off.

(8) and (12) *24-pin and 8-pin Connectors* – the 24-pin connector provides power to the majority of motherboard components, while the 8-pin connector supplies additional power.

(9) and (10) *SATA 3 and SATA 2 Connectors* – these interfaces are used to connect storage devices like hard drives, SSDs, and optical drives. On most motherboards, these connectors are arranged frontally and centrally for easy access.

(11) *POST Code Indicator* – found only on enthusiast motherboards, this indicator displays POST (Power-On Self-Test) codes and processor temperature, though its readings may sometimes be inaccurate.

(13) *Rear Panel with External Connectors* – this panel provides various ports for connecting peripheral devices such as a mouse, keyboard, speakers, headphones, and others.

Practical Part

Task 1. Identify the components of the personal computer shown in Figure 1.2 and complete Table 1.1.

Table 1.1.

№	Device Name	Purpose and Functions
1		
…		
9		

Fig. 1.2. Components of a Personal Computer

Task 2. Identify the components of the system unit of the personal computer shown in Figure 1.3 and complete Table 1.2.

Table 1.2.

№	Device Name	Purpose and Functions
1		
…		
9		

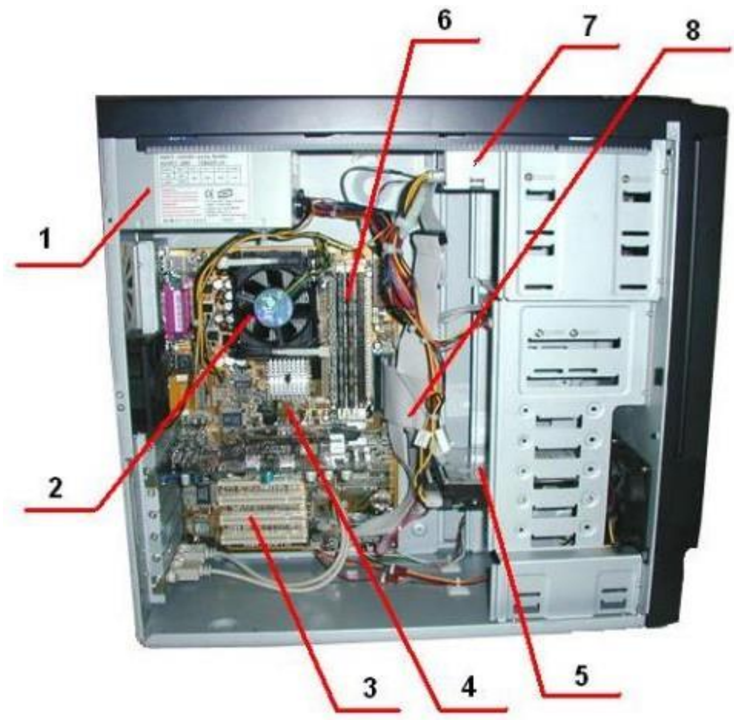

Fig. 1.3. Components of the System Unit of a Personal Computer

Task 3. Compare the ports located on the rear panel of your personal computer's system unit with the image in Figure 1.4. Label the ports shown in the figure.

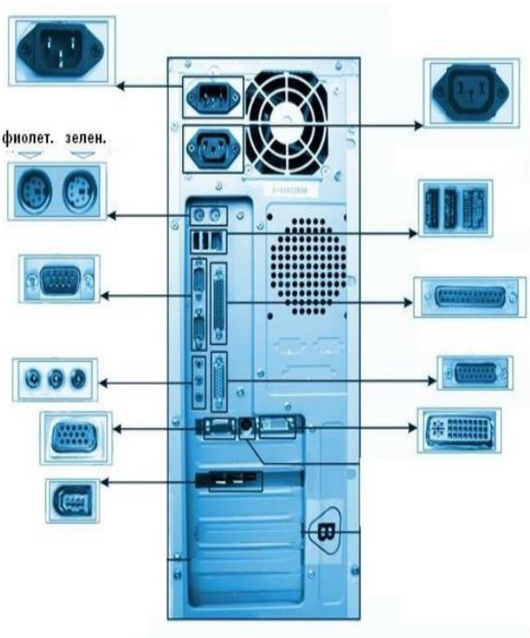

Fig. 1.4. The Location of Input and Output Ports on the PC System Unit

Task 4. Create a table indicating the names and purposes of the components of the motherboard of the PC shown in Figure 1.5.

Task 5. Determine the specifications of the motherboard for use in a gaming computer. Record all the necessary technical characteristics of the motherboard in Table 1.3.

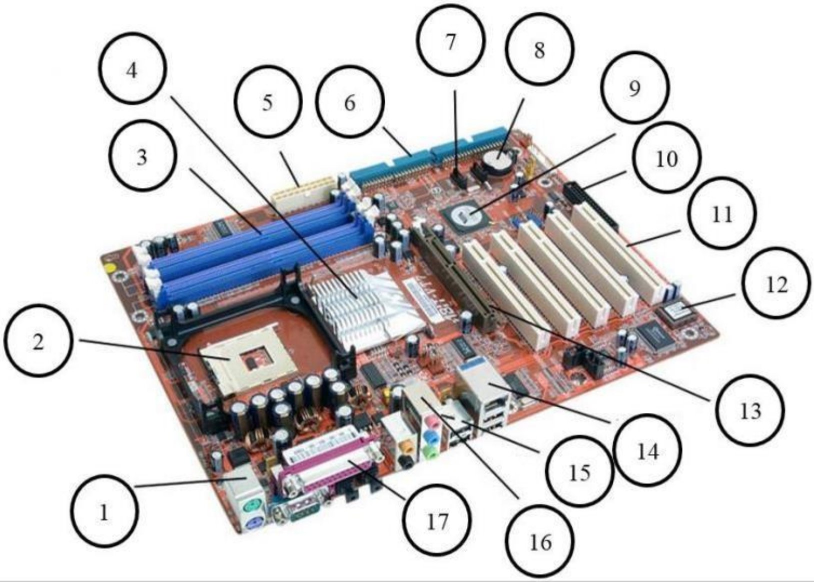

Fig. 1.5. Components of the PC Motherboard

Table 1.3

Motherboard Specifications

Characteristic	**Value of the characteristic**
Manufacturer	
Country of Manufacture	
Model	
Socket	
Chipset Model	
Type of RAM Slots	
Number of RAM Slots	
Number of AGP Slots	
Number of PCI-Express Slots	
Number of PCI Slots	

Number of Internal COM Ports	
Number of Internal USB Ports	
Number of CNR Slot Connectors	
Number of CD, Aux Connectors	
Number of ISA Slots	
Number of SATA Slots	
Number of IDE Slots	
Number of Floppy Slots	
Type of Connector for Power Supply	
Number of Fan Connectors	
Number of PS/2 Ports	
Number of COM Ports	
Number of LPT Ports	
Number of USB Ports	
Number of Game Ports	
Number of LAN Ports	
Number of VGA Ports	
Number of DVI Ports	
Number of Sound Card Connectors	
BIOS Version	
Form Factor	
Additional Characteristic	

Questions for independent training

1. What is a motherboard?
2. Name the main components of the motherboard.
3. What functions does the motherboard of a PC perform?
4. What is the form factor of a motherboard?
5. What is the purpose of the permanent memory chip?
6. What role does the battery on the motherboard play?
7. What is the purpose of the chipset?
8. What is the configuration of a computer? What are the types of configurations?
9. What is the structural composition of a PC?
10. Which devices are classified as input and output devices? What is their purpose?
11. Define "program" and "software."
12. Types of software and their purposes?
13. Define "personal computer."
14. What is "basic configuration" and what does it include?
15. What is located on the motherboard?
16. What types of memory are there and what are their characteristics?
17. How are computers classified by their areas of application?
18. What are the main blocks and components of a PC, and what are their functional descriptions?
19. How can you determine the type, capabilities, and technical specifications of a specific PC component?

Laboratory work 2

Basics of Number Systems. Conversion of Numbers Between Systems

Goals

Learn how to solve problems on the minimum number of bits required to represent different number systems in binary format.

Procedure:

1. Familiarize yourself with the theoretical information.
2. Complete the practical tasks.
3. Prepare a report on the laboratory work.
4. Answer the control questions.

Theoretical part

Table 2.1.

Number System

Binary	Символ	0,1
	База	2
Octal	Символ	0,1,2,3,4,5,6,7
	База	8
Decimal	Символ	0,1,2,3,4,5,6,7,8,9
	База	10

In the unary numeral system, the symbol 0 is used to represent numbers, and because only one symbol is used, the base of this system is 1.
In the binary system, we use the symbols 0 and 1, making the base 2, as it involves two symbols.
In the octal system, the symbols range from 0 to 7, providing 8

symbols, so the base is 8, which is the same for the decimal system.

A numeral system is a way of writing numbers; that is, a mathematical notation for expressing numbers from a specified set using digits or other symbols in a consistent manner.

The same sequence of symbols can represent different values in different numeral systems. For instance, "11" signifies the number eleven in the decimal system (the most commonly used system today), the number three in binary (used in modern computing), and the number two in the unary system (used for counting marks).

The value represented by a number is called its "value." Not all numeral systems can represent the same set of numbers; for example, Roman numerals cannot express the number zero.

Ideally, a numeral system:

- Represents a useful range of numbers (such as all integers or rational numbers).
- Provides a unique representation for each number (or at least a standard one).
- Reflects the algebraic and arithmetic properties of numbers.

For example, the decimal system uniquely represents each non-zero natural number as a finite sequence of digits starting with a non-zero digit.

Numeral systems are sometimes called "number systems," but this term can be ambiguous, as it may refer to different types of systems, such as real number systems, complex number systems, or p-adic number systems, which are beyond the scope of this article.

Procedure for completing the task:

1. Review the following Tasks 1-4.
2. Select the task according to your variant from the task tables and solve them.

Task 1. Find the minimum number of bits required to represent $(4113)_{10}$ in binary form. In this case, we are not concerned with the binary equivalent of the decimal number 4113; instead, we need to determine the minimum number of bits required in binary if we convert it to binary format. This is done using the general n-digit number with base b (Figure 2.1).

Fig. 2.1. General n-digit number

We can represent 0 in base b raised to the power of n-1 (Fig. 2.2).

Fig. 2.2. "0" raised to the power of n-1.

Therefore, if we consider base 2, the converted binary number 4113 can take any value from 0 to b raised to the power of n-1. Thus, it can be said that the binary equivalent of 4113 cannot be greater than b raised to the power of n-1 (Fig. 2.3).

Fig. 2.3. Binary equivalent

Therefore, we can say that $(b^n-1)\geq 4113$, so $(b^n - 1) \geq 4113$. In general, we added ones to both sides. If we apply the logarithm with base bb to both sides, we get:

$$n \geq \log_b(4114) \tag{2.1}$$

Since we are converting from decimal to binary, the base will be 2. Now we can find the minimum number of bits by applying the logarithm:

$$n \geq \log_2(4114) \tag{2.2}$$

This equals:

$$n \geq 12.006326 \tag{2.3}$$

Since the number of bits cannot be a fractional value and must be an integer, we round the number, and the minimum number of bits required to represent the decimal number 4113 in binary is 13.

Task 2. Find the minimum number of bits required to represent the octal number 521 in binary form. First, we need to convert this number into decimal form:

$$(521)_8 = 5*8^2+2*8^1*8^0=320+16+1=(337)_{10} \tag{2.4}$$

Now, the binary equivalent will range approximately from 0 to 2 raised to the power of n-1 (see Fig. 2.4).

Figure 2.4. Binary equivalent

Therefore, we can say that $(2^n - 1) \geq 337$, which implies $2^n \geq 338$. Now, applying the logarithm with base 2 to both sides, we get $n \geq \log_2(338)$. Solving the logarithm, we obtain $n \geq 8{,}40087943628$. By applying the rule from the previous task, we find that the minimum number of bits required to represent the octal number 521 in binary form is 9.

Task 3. Consider the equation $(123)_4=(a6)_b$. Find the possible values of aa and bb.
Solution: 1. First of all, a<b. Explanation: Recall that in numeral systems, the base is always greater than the symbols used in the system. For example, in the decimal system, the base is 10, and all symbols range from 0 to 9, which are always smaller than the base (10). Therefore, we can say that b > 6.
Now, to find the values of aa and bb, we need to use the equation $(123)_4=(a6)_b$. Next, we need to convert both sides of the equation into a common numeral system. Let's start with the left side of the equation, which is $(123)_4$. Convert this number into decimal form:

$$(123)_4=1*4^2+2*4^1 3*4^0=16+8+3=27_{10} \qquad (2.5)$$

Now let's convert the right side:

$(a6)_b=a*b^1+б*b^0=(ab+6)_{10}$, which gives the equation: $27_{10}=(ab+6)_{10}$, so ab+6=21, ab = 21.

Now it will be easy to determine the possible values of aa and bb. Since a=21, b = 21, we can assume that:

- If a=1, b=21,
- If a=3, b=7, again 21,
- If a=7, then b=3, again 21,
- If a=21, b = 1.

These are all the possible solutions for aa and bb (see Figure 2.5).

a	b
1	21 >6
3	7 >6
7	3 >6
21	1 >6

Figure 2.5. Solution table

We had the condition that b > 6, and from the table, we can see that this applies to rows 1 and 2. Therefore, the possible values for a and b are: a = 1, b = 21 and a = 3, b = 7.

Task 4. Consider the equation $(42)_9=(a3)_b$. Find the possible values of a.

Solution: We define the conditions for the right-hand side: a<b та b>3.

Let's perform the conversion to decimal:

$$(42)_9=4*9^1+2*9^0=38_{10} \quad (2.6)$$

Now, for the right-hand side, we have:

$$(a3)_b=a*b^1+3*b^0= (ab+3)_{10} \quad (2.7)$$

This gives the equation:

$$38_{10}=(ab+3)_{10} \quad (2.8)$$

Simplifying:

$$ab+3=38, ab=35 \quad (2.9)$$

Now, we need to find the possible values for aa and bb. We will create a table similar to the one in Task 3.

a	b
1	35 >3
5	7 >3
7	5 >3
35	1 >3

Figure 2.6. Solution Table

Based on the table, the conditions of the problem are satisfied by rows 1, 2, and 3. However, according to the initial condition, a<b, the valid rows are 1 and 2. Therefore, the possible values for aa are a=1 and a=5.

Table 2.2.

Variant selection table for Tasks 1-4.

Find the minimum number of bits required to represent $(X)_{10}$ in binary form. X is your value according to the variant.	
Variant	**Equation**
1	$(4115)_{10}$
2	$(4313)_{10}$
3	$(5897)_{10}$
4	$(3571)_{10}$
5	$(2597)_{10}$
6	$(1892)_{10}$
7	$(6112)_{10}$
8	$(7259)_{10}$
9	$(3236)_{10}$
10	$(1269)_{10}$
11	$(2897)_{10}$
12	$(1544)_{10}$
13	$(8745)_{10}$
14	$(6248)_{10}$
15	$(5796)_{10}$

Questions for independent training

1. What is a numeral system? What is the difference between a positional numeral system and a non-positional numeral system?
2. What is the base of a numeral system?
3. State the general rule for converting numbers from any numeral system to the decimal system.
4. Formulate an algorithm for converting fractional numbers, where the integer part equals 0, from one numeral system to another.

Laboratory work 3

Central and External Computer Devices

Goals

Study of the functional interaction between central and external computer devices and their characteristics.

Procedure:

1. Familiarize yourself with the theoretical information.
2. Complete the practical tasks.
3. Prepare a report on the laboratory work.
4. Answer the control questions.

Theoretical part

A personal computer (PC) in its basic configuration typically includes the following components: the system unit, monitor, keyboard, and a pointing device (mouse).

The system unit's case is a rectangular shape made from sheet metal (such as steel or aluminum alloy), housing all the necessary components for the PC's operation. The manufacturer of the case is not important, as all cases follow a standardized specification known as the form factor.

The form factor defines the technical standards of a product, including details like shape, size, connector placements, ventilation needs, weight limits, and other characteristics. There are two main types of PC case form factors: AT and ATX.

The AT form factor (short for "Advanced Technology") was the first widely adopted standard for personal computers during the 1980s, particularly with processors like the 286 and early Pentium-1. It was developed by IBM in 1984 and replaced earlier standards like the PC and XT. However, the AT form factor is no longer in use.

The ATX form factor (from "Advanced Technology Extended") was introduced for desktop PCs in 1995 by INTEL, addressing the growing power demands of personal computers, the increase in external devices, and the integration of components on the motherboard, which required improved cooling. The ATX form factor has since become the standard for mass-produced computers starting from 2001.

System unit cases are categorized by size, as shown in Table 3.1.

Table 3.1.

Sizes of PC System Unit Cases

Case Type	**Height (cm)**	**Width (cm)**	**Length (cm)**
Desktop	20	45	45
Slimline	7	35	45
Mini Tower	45	20	45
Midi Tower	50	20	45
Big Tower	65	20	48
Super Big Tower	75	22	48
File Server	75	35	55

The selection of the correct form factor for a computer significantly influences various important factors, such as noise levels, case temperature, and ventilation. These elements, in turn, affect the performance of the internal components of the system unit, particularly the hard drive, central processing unit, and other internal parts.

The ATX form factor specifies the following critical characteristics of a PC:

- The physical dimensions of motherboards;
- General guidelines for the placement of connectors and ports on the case;
- The location of the power supply unit within the case;
- The physical size of the power supply unit;
- The electrical specifications and color coding of power supply cables;
- The shape and positioning of various connectors (including power supply connectors).

For example, the wire color standards for ATX are outlined in Table 3.2.

Table 3.2.

ATX Standard Wire Color Code

Circuit	**Wire Color**	**Explanation**
+5V	Red	Main power
+12V	Yellow	Power for device motors and interface circuits
-5V	White	Not used. Present for ISA Bus standard compliance
-12V	Blue	Power for interface circuits
+3,3V	Orange	Power for the processor
+3,3V Sence	Brown	Feedback signal from the regulator

+5VSB	Pink	Standby low-power +5V source
PS-ON	Green	Power-on signal
PW-OK	Gray	"Power good" signal
GND	Black	Ground wire relative to power voltages

The system unit case houses the following components:

- Motherboard (mainboard)
- Power supply unit
- Hard disk drive
- Floppy disk drive
- CD/DVD drive
- Expansion cards (installed in motherboard slots and secured to the rear of the case)

The motherboard is a critical part of a personal computer. Its quality and performance have a direct impact on the stability and speed of the entire system. The motherboard defines essential parameters of the computer, such as processor and memory types, which influence the overall performance, as well as practical aspects like form factor, number of expansion slots, and the presence of integrated devices. These factors also affect the computer’s consumer features and potential areas of use.

Key components of the motherboard include:

- Processor socket
- Main chipset
- BIOS chip (Basic Input Output System)
- RAM slots
- Expansion card slots
- Connectors for IDE or SCSI devices and FDD
- Additional connectors for front panel buttons and indicator lights

- External ports for peripherals like keyboard, mouse, printer, USB bus, etc.

The motherboard's size is also determined by its form factor, with the main form factors listed in Table 3.3.

Table 3.3.

Motherboard Form Factors

Form factors	**Physical dimensions (mm)**	**Specification (year)**	**Note**
XT	(8,5 × 11)″ (216 × 279)	IBM, 1983	IBM PC XT architecture
AT	(12 × 11 – 13)″ (305 ×279÷330)	IBM, 1984	IBM PC AT architecture (Desktop/Tower)
ATX	(12 × 9,6)″ (305 × 244)	Intel, 1995	For system units MiniTower, FullTower types
Mini ATX	(11,2 × 8,2)″ (284 × 208)	Intel, 1995	For Tower-type and compact Desktop system units
Micro ATX	(9,6 × 9,6)″ (244 × 244)	Intel, 1997	Has fewer slots than ATX

The following components are directly installed on the motherboard:

- Processor
- Processor heatsink with fan
- RAM modules

- Expansion cards (secured with screws to the rear of the system unit)

Other parts, such as the power supply unit, hard disk, floppy disk drive, and CD/DVD drive, are placed in designated compartments within the system unit case and attached using screws.

Procedure:

1. *Identification of system unit components*

Obtain the set of components needed for assembling the PC system unit from the instructor. Identify the form factor of the PC case. Carefully arrange the components on the table, determine their purpose, and complete Table 3.4 (or describe your personal computer if applicable).

2. *Identification of motherboard components*

Identify the locations of the main installed components on the motherboard, as well as the ones that are not installed, and fill in Table 3.5.

Task: Complete the tables as per the procedure, indicating the specifications of your PC.

Table 3.4.

Main Components of a PC System Unit

№	**Component Name**	**Model, Type, Functional Purpose**
1.	Case Form Factor	
2.	Motherboard	
3.	Power Supply Unit	
4.	Hard Disk	
5.	Floppy Disk Drive	
6.	CD/DVD Drive	
7.	Cooler	
8.	Other	

Table 3.5

Main Components of a PC Motherboard

№	**Component Name**	**Installed Components (or Components to be Installed)**	**Model, Type, Functional Purpose**
1.	Socket for processor installation		
2.	Processor		
3.	Processor heatsink with cooler		
4.	Chipset		
5.	RAM modules		
6.	BIOS chip		
7.	Expansion card slots		
8.	Expansion cards		
9.	External ports for keyboard		
10.	External ports for mouse		
11.	External ports for printer		
12.	Internal USB buses		
13.	External USB ports		
14.	Other		

Questions for independent training

1. What are the main blocks and boards that make up a personal computer?
2. What is the standard power supply wattage? What voltages does the power supply provide? What are the main reasons for the failure of a power supply?
3. What types of cases are used in PCs?
4. What are the main components found on the motherboard?
5. What is the purpose of the permanent storage device?
6. How are interrupts used in computer systems to handle external device requests efficiently?
7. What are the primary differences between direct memory access (DMA) and interrupt-driven I/O? How do these techniques improve the performance of I/O operations?
8. Describe the role of peripheral devices (e.g., keyboard, mouse, printer, scanner) in a computer system and how they interface with the central unit.
9. How do external storage devices like hard drives, SSDs, and optical drives differ in terms of speed, capacity, and technology?
10. Explain how data is transferred between the CPU and peripheral devices using a bus. What types of buses are commonly used in modern computers?

Laboratory work 4

Study of the operation of power supply units in desktop computers

Goals

An overview of the principles behind the design of power supply units for desktop computers, the technology involved in their operation, and the processes used to convert alternating current (AC) from the electrical grid into direct current (DC) for powering computer components.

Procedure:

1. Familiarize yourself with the theoretical information.
2. Complete the practical tasks.
3. Prepare a report on the laboratory work.
4. Answer the control questions.

Theoretical part

The power supply unit of a desktop computer is a secondary power source designed to deliver direct current (DC) electrical energy to the computer’s components. Its primary functions are to convert the AC mains voltage to the required DC voltage, stabilize the output, and protect against minor disruptions from the power grid. Additionally, the built-in fan aids in cooling the system unit. The power supply uses semiconductor diodes to convert alternating current (AC) into direct current (DC).

A semiconductor diode is the simplest type of semiconductor device, consisting of a single PN junction. Its main role is to allow current to flow in one direction while preventing it from flowing in the opposite direction. The diode is made up of two layers of semiconductor material, one of type N and the other of type P, as illustrated in Figure 4.1.

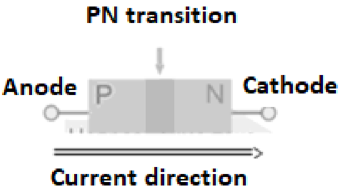

Figure 4.1. The structure of the diode

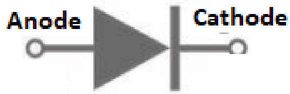

Figure 4.2. Designation of the diode on electrical diagrams

The diode symbol in electrical circuits is illustrated in Figure 4.2. When no voltage is applied to either the anode or the cathode, the diode remains in an idle state. The N-region contains free electrons, which are negatively charged, while the P-region has positively charged ions, or holes. At the junction between these regions, an electric field forms due to the presence of oppositely charged particles, which attract each other.

This electric field causes free electrons in the N-region to drift across the PN junction into the P-region, where they fill some of the holes. This results in a very small electric current, measured in nanoamperes. As a result, the material density in the P-region increases, and diffusion (the tendency of matter to evenly distribute itself) takes place, pushing the particles back toward the N-region [2, p. 48].

If the positive terminal of the power supply is connected to the cathode and the negative terminal to the anode, the electrons in the N-region are attracted to the positive terminal and move away from the PN junction. Likewise, holes in the P-region are drawn toward the negative terminal, also moving away from the PN junction. This causes an increase in material density at the electrodes. Diffusion then occurs, pushing particles back to achieve a uniform density. As a result, the diode does not conduct current.

If the positive terminal is connected to the anode and the negative terminal to the cathode, a repulsive force is created between similarly charged particles. Electrons are repelled from the negative terminal and move toward the PN junction. At the same time, holes in the P-region are repelled by the positive terminal and move toward the electrons. This creates an accumulation of opposite charges at the PN junction, forming an internal electric field. Under the influence of this field, electrons begin to drift toward the P-region, where some recombine with holes, while others continue toward the positive terminal of the power supply. This allows current to flow through the diode, a property used in power supplies for desktop computers.

The main task of the power supply unit (Fig. 4.3) is to convert the alternating voltage from the 220 V, 50 Hz mains into the supply voltage for the computer's components, which is ± 12 V, ± 5 V, and ± 3.3 V [3, p. 47].

Figure 4.3 – External appearance of the computer power supply unit.

In the past, linear power supplies that relied on power transformers and weighed up to 6 kg were used for this purpose. Today, modern power supplies are designed with switch-mode technology and weigh as little as 1 kg. Figure 4.4 shows the block diagram of a switch-mode power supply that converts 220 V AC into 12 V DC.

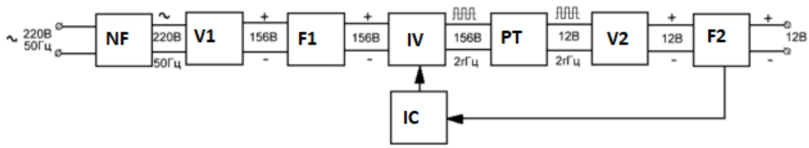

Figure 4.4 – Block diagram of the computer switch-mode power supply.

Designations on the diagram:

NF – Network filter, its task is to minimize network interference, both incoming and outgoing, caused by the operation of the power supply unit.

V1 – First voltage rectifier, built on diodes. Its task is to convert the AC voltage into pulsating DC of one polarity, with a constant component present.

F1 – First smoothing filter. Its task is to smooth the ripples and produce true DC voltage.

IV – Voltage inverter. It generates a high-frequency square pulse voltage.

PT – Pulse transformer. Its task is to step down the voltage to the required level and provide galvanic isolation between the circuits. Due to the use of high-frequency square pulse voltage, its size and weight are significantly smaller than those of a transformer in linear circuits.

V2 – Second voltage rectifier, built on diodes.

F2 – Second smoothing filter.

IC – Inverter controller. Its task is to control the inverter and stabilize the output voltage of the power supply unit through feedback. To generate the 4.3 V and 5 V DC voltages, several secondary windings of the pulse transformer are used.

Procedure for completing the task:

4.1. *Study of the input voltage.*
Assemble the circuit according to Figure 4.5.

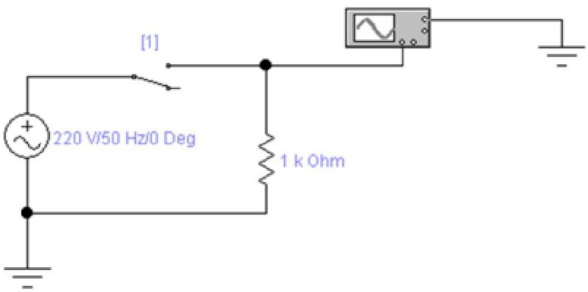

Figure 4.5 – Circuit for studying the input voltage.

After setting up the oscilloscope, use the "Snipping Tool" in the Windows operating system to capture the voltage waveform and include it in the report, specifying the frequency and voltage value.

4.2. Study of the voltage rectifier.

Assemble the circuit according to Figure 4.6. This is a so-called half-wave rectifier.

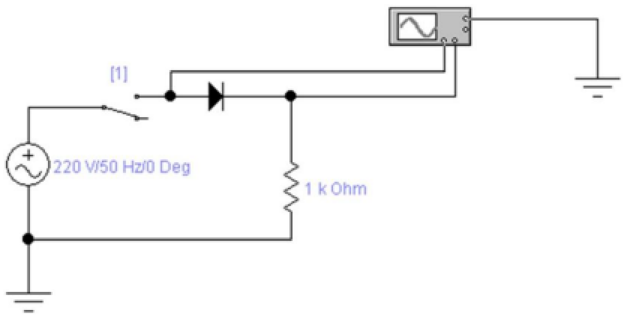

Figure 4.6 – Circuit for studying the half-wave rectifier.

After setting up the oscilloscope, use the "Snipping Tool" in the Windows operating system to capture the voltage waveforms (voltage curves) at the input and output of the circuit and insert them into Table 4.1. Explain the changes observed in the waveform.

4.3.Study of the capacitor's impact on the process.

Assemble the circuit according to Figure 4.7.

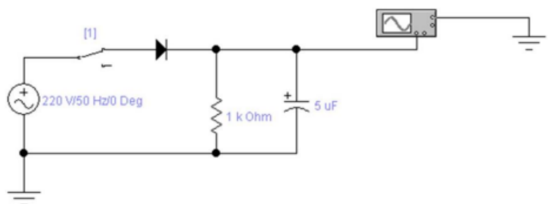

Figure 4.7 – Circuit for studying the impact of the capacitor on the process.

Copy the voltage waveform at the output of the circuit with a 5 μF capacitor value into Table 4.1. By changing the capacitor's capacitance, capture the corresponding waveforms and insert them into Table 4.1. Draw a conclusion about the effect of the capacitor's capacitance on the output voltage.

Table 4.1

Dependence of voltage waveforms on the capacitor's capacitance

Voltage waveform ⇒ at the input of the circuit	
Capacitance of the capacitor	Voltage waveform at the output of the circuit
Capacitor is absent	
5 μF	
20 μF	
50 μF	
100 μF	

4.4. Study of the full-wave rectifier.

The discussed rectifier circuits use only the positive component of the output alternating current, meaning that 50% of the energy is lost. This drawback is eliminated using a bridge circuit, which contains 4 diodes arranged in a specific way. Assemble the circuit according to Figure 4.8.

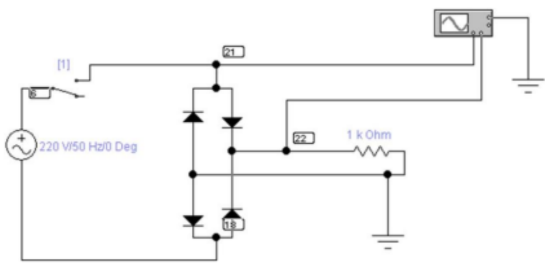

Figure 4.8 – Circuit for studying the bridge rectifier circuit

After setting up the oscilloscope, copy the voltage waveform at the input (node 21) and output (node 22) of the circuit into Table 4.2. Explain the changes in the waveform compared to the circuit in Figure 4.7. Discuss how the bridge rectifier circuit works.

Table 4.2

Dependence of voltage waveforms on the capacitor's capacitance in the bridge rectifier circuit

Voltage waveform ⇒ at the input of the circuit	
Capacitance of the capacitor	Voltage waveform at the output of the circuit
Capacitor is absent	
5 μF	
20 μF	
50 μF	
100 μF	

Assemble the circuit according to Figure 4.9.

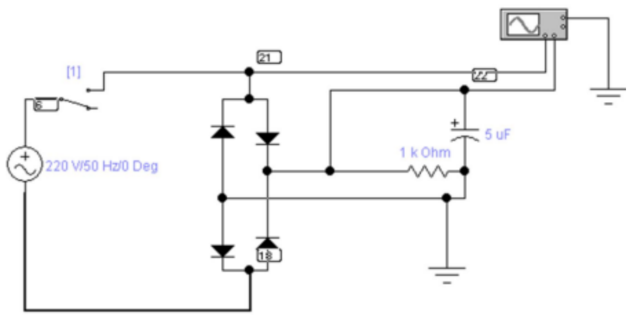

Figure 4.9 – Circuit for studying the bridge rectifier circuit with a capacitor

Copy the voltage waveform at the output of the circuit with a 5 μF capacitor value into Table 4.2. By changing the capacitance of the capacitor, capture the corresponding waveforms and insert them into Table 4.2. Draw a conclusion about the effect of the capacitor's capacitance on the output voltage. Compare the voltage waveforms in Tables 4.1 and 4.2 with the same capacitor values. Make conclusions based on these comparisons.

4.4. Study of the main part of the power supply: "Voltage Inverter – Output Filter."
Assemble the circuit according to Figure 4.10.

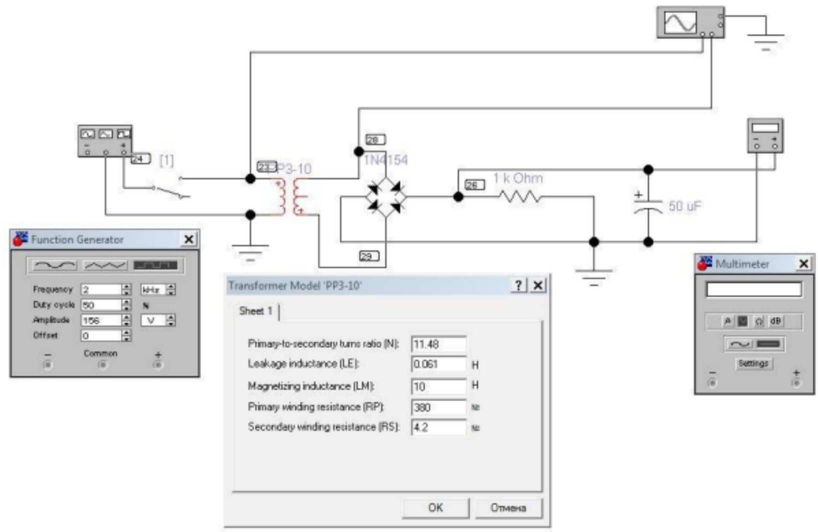

Figure 4.10 – Circuit for studying the main part of the power supply.

A functional generator is used as the voltage inverter. Its settings are provided in the corresponding window.

A step-down pulse transformer, model PP3-10 from the powrvolt group, is used. Its settings are provided in the corresponding window.

A bridge rectifier from the Diodes group is used as the rectifier. It operates similarly to the bridge rectifier shown in Figure 4.9 and allows setting the model for all diodes in the bridge simultaneously.

An electrolytic capacitor with a 50 μF rating is used as the output filter (F2 in Figure 4.4).

The recommended settings for the oscilloscope are provided in Figure 4.11.

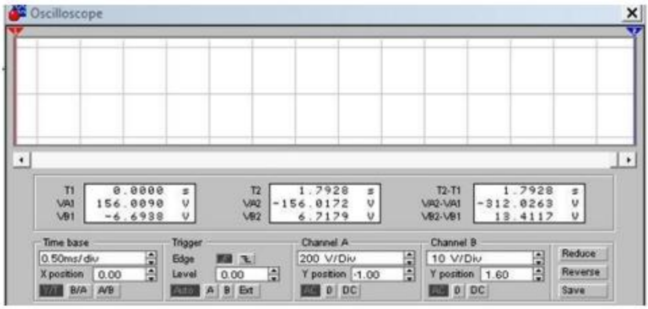

Figure 4.11 – Recommended oscilloscope settings

After setting up the oscilloscope, capture the voltage waveform at the input of the pulse transformer (node 23) and its output (node 28) in the report. By changing the transformer parameter N, determine what it represents and how it affects the output voltage.

Questions for independent training

1. What is the role of the power supply in a computer?
2. What types of power supplies are used in technology?
3. How does a switch-mode power supply work, and what advantages does it have over a linear power supply?
4. What is the characteristic of semiconductor conductivity?
5. What is the purpose of semiconductor diodes?
6. What rectifier circuits are used in technology?
7. How are current ripples smoothed in rectifiers?
8. How does the power supply unit affect the power consumption of the computer and its energy efficiency?
9. What types of cooling methods are used in power supplies to ensure their proper operation?
10. How is the output voltage of a power supply measured, and what should be done if the voltage exceeds the acceptable range?
11. What factors can influence the performance of a power supply in real-world conditions?
12. What dangers can arise from faulty power supply operation, and what diagnostic methods are used to detect failures?
13. What are the main components of a power supply unit, and how does their role affect the functioning of the device?
14. How can a power supply unit be tested for stability and efficiency in a laboratory setting?

Laboratory work 5

Study of the arithmetic-logic unit

Goals

Get acquainted with the design and functioning principles of the processor's arithmetic-logic unit.
Identify the types of operations that the arithmetic-logic unit can execute using the truth table.
Learn the methods for controlling the processor's arithmetic-logic unit.

Procedure:

1. Familiarize yourself with the theoretical information.
2. Complete the practical tasks.
3. Prepare a report on the laboratory work.
4. Answer the control questions.

Theoretical part

The central component of a computer is the arithmetic-logic unit (ALU), responsible for executing the instructions of the current program. In its most basic form, it consists of the ALU itself, a control unit, a register block, and control and data buses. Each program instruction contains an operation code, which is decoded by the control unit. This causes the ALU circuit to activate the appropriate operation using the data from the data registers. The ALU is primarily composed of identical single-bit ALUs, each of which performs all functions on a single bit of a parallel word. Figure 5.1 illustrates the configuration of such an ALU, along with the control unit that performs a limited set of operations [7, p. 192].

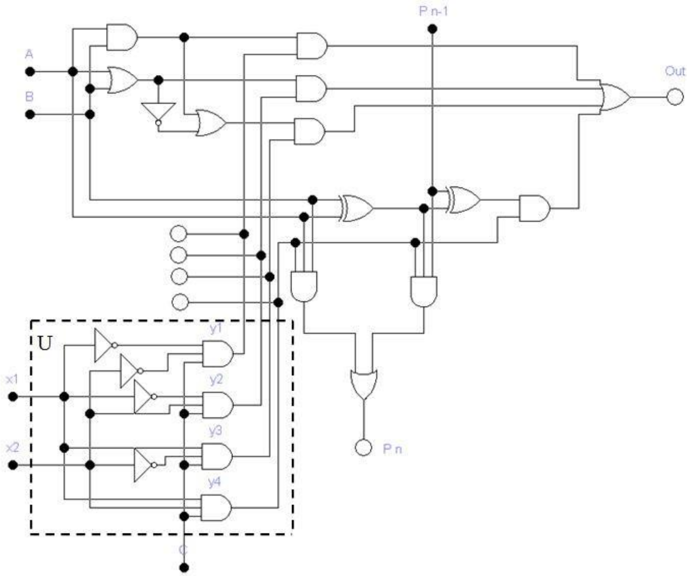

Figure 5.1 – Single-bit ALU

The inputs A and B receive the respective bits of the two numbers involved in the operation. The inputs x1 and x2 carry the operation code to be executed on these numbers. This operation code is identified in node U (the type of which needs to be determined), which configures the ALU to perform the required operation. The operation is initiated by a sync signal applied to input C. The result of the operation is sent to the output Out, and in some cases, it is passed through output Pn to the higher bit of the ALU. Information from the lower bit of the ALU is received through input Pn-1.

While modern processors have ALUs that are much more complex than the one described here, the fundamental operational principle remains the same.

Procedure for completing the task:

5.1. Create a Word document in the application for generating the report, and include the title of the laboratory work and the details of the performer.
5.2. Download the ALU diagram implemented in Electronics Workbench from the online course "Computer System Architecture" or obtain it from the instructor. Include the diagram in the laboratory report.
5.3. Copy the empty Table 5.1 into the report.

Table 5.1

Truth Table for Node U

X1	X2	Y1	Y2	Y3	Y4
0	0				
0	1				
1	0				
1	1				

♦ Attention. Closing the switch initiates the application of a logical one to the input of the circuit. A lit Red Probe indicates the presence of a logical one at the corresponding output of the circuit, while a dimmed Red Probe indicates the presence of a logical zero at the corresponding output.

Set input "C" to a high state. By alternately sending 0 and 1 to the inputs x1 and x2 from the source, and recording the signal values at the outputs y1, y2, y3, and y4, fill in Table 5.1. Determine which typical computer node is implemented by block U and what function it performs in the ALU. Write the answers in the report.

5.4. Set the inputs x1 = 0, x2 = 0, C = 1. By alternately sending 0 and 1 to the inputs A and B from the sources, and recording the signal values at the outputs Out and Pn, fill in Table 5.2.

Table 5.2

Truth Table for the experiments in section 5.4.

A	B	Out	Pn
0	0		
0	1		
1	0		
1	1		

Formulate the operation performed by the ALU in this mode. By pressing the switch Pn-1, determine its effect on the ALU's operation.

5.5. Set the inputs x1 = 1, x2 = 0, C = 1. By alternately sending 0 and 1 to the inputs A and B from the sources, and recording the signal values at the outputs Out and Pn, fill in Table 5.3.

Table 5.3

Truth Table for the experiments in section 5.5.

A	B	Out	Pn
0	0		
0	1		
1	0		
1	1		

Formulate the operation performed by the ALU in this mode. By pressing the switch Pn-1, determine its effect on the ALU's operation.

5.6. Set the inputs x1 = 0, x2 = 1, C = 1. By alternately sending 0 and 1 to the inputs A and B from the sources, and recording the signal values at the outputs Out and Pn, fill in Table 5.4.

Table 5.4

Truth Table for the experiments in section 5.6.

A	B	Out	Pn
0	0		
0	1		
1	0		
1	1		

Formulate the operation performed by the ALU in this mode. By pressing the switch Pn-1, determine its effect on the ALU's operation.

5.7. Set the inputs x1 = 1, x2 = 1, C = 1. By alternately sending 0 and 1 to the inputs A, B, and Pn-1 from the sources, and recording the signal values at the outputs Out and Pn, fill in Table 5.5.

Table 5.5

Truth Table for the experiments in section 5.7.

A	B	Pn-1	Out	Pn
0	0	0		
1	0	0		
0	1	0		
1	1	0		
0	0	1		
1	0	1		
0	1	1		
1	1	1		

Formulate the operation performed by the ALU in this mode.

Questions for independent training

1. What is the ALU?
2. Which processor block controls the ALU and how?
3. Where is the information processed in the ALU stored?
4. What is the name of the dedicated part of the ALU in computing technology? (see Figure 5.2).

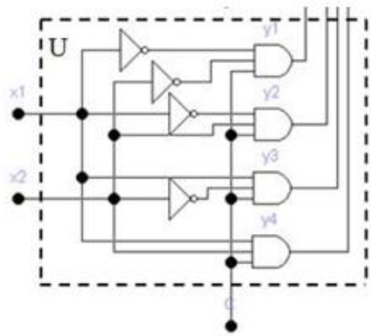

Figure 5.2 – Block U of the Arithmetic Logic Unit (ALU)

5. What is input to it and what is produced at the output?
6. A code of 10 (x1 = 1, x2 = 0) is applied to the input of block U. Determine which signals will be formed at the outputs y1, y2, y3, y4.
7. What operations can the ALU investigated in the work perform?
8. How is the selection of the operation performed by the ALU?

Bibliography

1. Hwu W.-M.W., Kirk D.B., Hajj I.E. Programming Massively Parallel Processors: A Hands-on Approach. 4th ed. Cambridge : Morgan Kaufmann, 2022. 580 p.

2. Deakin T., Mattson T. G. Programming Your GPU with OpenMP: Performance Portability for GPUs. Cambridge : Morgan Kaufmann, 2023. 336 p.

3. Barlas G. Multicore and GPU Programming: An Integrated Approach. 2nd ed. Burlington : Morgan Kaufmann, 2022. 1024 p.

4. Hennessy J. L., Patterson D. A. Computer Architecture: A Quantitative Approach. 6th ed. Cambridge : Elsevier, 2017. 992 p.

5. Tanenbaum A. S. Structured Computer Organization. 6th ed. Upper Saddle River : Pearson Custom Publishing, 2013. 544 p.

6. Bishop R. L. The Architecture of Computer Hardware and Systems Software. 3rd ed. Hoboken : Wiley, 2005. 456 p.

7. Morse L. Computer Organization and Design: The Hardware/Software Interface. 5th ed. Berkeley : University of California, 2014. 720 p.

8. Darringer D. J. Advanced Computer Architecture. El Kuwait : Kuwait University, 2016. 352 p.

9. Petrosyan O. O. Computer Architecture. Kyiv : Kondor, 2010. 368 p.

10. Melnyk M. I. Architecture of Computers and Systems. Lviv : Lviv Polytechnic, 2018. 450 p.