Ministry of Education and Science of Ukraine
National Aerospace University
"Kharkiv Aviation Institute"

Department of Aircraft Control Systems (Dept. 301)

APPROVED:

Guarantee of the educational program

_____ A. Kulik

"27" 08 2021

WORK PROGRAM OF THE COMPULSORY DISCIPLINE

MICROCONTROLLERS

Field of Study: 17 – Electronics and Telecommunication

Program Subject Area: 173 – Avionics

Educational Program: Systems of Autonomous Navigation and Adaptive Control of Aircrafts

Level of Qualification: 1-st (bachelor degree)

Kharkiv 2021

The developed study program of compulsory discipline « Microcontrollers» is for English-speaking students of training direction 173 − Avionics

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Developer: Dzhulgakov V., docent of dept. 301 _____

(sign)

The program has been examined at the meeting of dep. 301 «Aircraft Control Systems».

Record of proceeding: № 1 from " 27 " August 2021

Head of the department
Associate professor, PhD (Engineering) _____ K.Yu. Dergachov

(sign)

1. Course description

<table>
<tr><td colspan="2" rowspan="2">Indices</td><td colspan="2" rowspan="2">Field of study, Program subject area, Educational program</td><td colspan="2">Course specification</td></tr>
<tr><td colspan="2">Full-time study</td></tr>
<tr><td colspan="2">ECTS credits – 9</td><td colspan="2" rowspan="3">Branch of Education:
17 – Electronics and Telecommunication</td><td colspan="2">Professional training area</td></tr>
<tr><td colspan="2">Modules – 4</td><td colspan="2" rowspan="2">Academic year:</td></tr>
<tr><td colspan="2">Semantic modules – 4</td></tr>
<tr><td colspan="2" rowspan="2">Individual Assignment
_____
(topic name)</td><td colspan="2" rowspan="3">Program subject area:
173 – Avionics</td><td>2021-2022</td><td>2021-2022</td></tr>
<tr><td colspan="2">Semester</td></tr>
<tr><td>6-th</td><td>7-th</td></tr>
<tr><td colspan="2">Total hours – 270</td><td colspan="2" rowspan="3">Educational Program:
Systems of Autonomous Navigation and Adaptive Control of Aircrafts</td><td colspan="2">Lectures[1)]</td></tr>
<tr><td colspan="2">Academic hours per week for full-time study</td><td>32 hrs.</td><td>16 hrs.</td></tr>
<tr><td colspan="2">Semester 6</td><td colspan="2">Tutorial classes</td></tr>
<tr><td>classroom
4 hrs.</td><td>self-study
4,5 hrs.</td><td colspan="2" rowspan="3">Level of qualification:
1st (batchelor degree)</td><td>–</td><td>–</td></tr>
<tr><td colspan="2">Semester 7</td><td colspan="2">Lab classes (practical)</td></tr>
<tr><td colspan="2"></td><td>32 hrs.</td><td>32 hrs.</td></tr>
<tr><td>classroom
4 hrs.</td><td>self-study
4,5 hrs.</td><td colspan="2" rowspan="5"></td><td colspan="2">Self-study (unaided) work</td></tr>
<tr><td colspan="2" rowspan="4"></td><td>71 hrs.</td><td>71 hrs.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Assessment form</td></tr>
<tr><td>Exam</td><td>Exam</td></tr>
</table>

Note: ratio of classroom working and unaided (self-study) work makes:
128/142 (under full-time education).

2. Purpose and objectives of academic discipline

Learning Aim is to learn principles of typical structure of basic single-chip microcontrollers (MC), developing approaches for digital controllers based on MC and software design technology.

Training objectives are to obtain abilities of analysis of technical requirement for digital controller design and reasonable choice of digital units for implementation of the controller; to master basic approaches and technologies of software design and debugging for digital controllers (data acquisition and processing in real-time mode).

Learning Outcomes

On successful completion of the subject, students

should know:

- basic functional parts and units of digital circuitry;
- approaches to calculate parameters of digital units;
- typical structure of a single-chip microcontroller, its operation principles; approaches to build digital controller based on it;
- typical bus-based microprocessor system structure;
- typical functional and circuit diagrams of input-output units for discrete and analog signals;
- principles of single-chip microcontroller software design;
- generalized methods to design digital controller for automatic control systems.

should be able to:

- calculate the typical functional blocks of digital circuitry;
- form a functional and schematic diagram of the digital controller;
- develop algorithms and software for controller to solving typical functional control problems;
- debug and test software for digital controller.

have a general notion:

- up-to-date single-chip microcontrollers and input-output units;
- event-oriented and real-time control software design approaches.

3. Content of the course

Module 1. Circuitry of digital units

Semantic modulus 1. Circuitry of basic digital units

Topic 1. Introduction to discipline «Microcontrollers»

Subject and tasks of the discipline «Microcontrollers». Typical structure of digital control system. Connection with previously studied disciplines. Topic literature review.

Topic 2. Basic logic functions and logic gates. Design of combinational circuits

Analog and discrete signals. Information presentation parameters. Basic of Boolean algebra. Basic logic functions and logic gates. Formal description of logic devices. Stages of combinational circuits designing and approaches to its implementation. Stages of combinational circuit analytic synthesis and implementation tools.

Topic 3. Integrated combinational discrete devices

Features of combinational discrete devices. Multiplexers, decoders, coders, adders, comparators schematic and functioning. Various types of decoders. Demultiplexers, coders, arithmetic-and-logic units. Digital comparators.

Topic 4. Discrete devices with memory. Implementation and using devices with memory

Features of description and operation logic circuits with memory. Various triggers, registers and counters building and operation. Up-to-date series of integrated circuits. Counters design approach.

Topic 5. Storage integrated circuits

Classification of storage integrated circuits. Structure and electrical interface of storage integrated circuits.

Module 2. Architecture and programming of single-chip microcontrollers of the MCS-51 family

Semantic modulus 2. Architecture and programming of single-chip microcontrollers of the MCS-51 family

Topic 6. Classification of microprocessors. Features of the architecture and software of digital controllers

Microprocessor device as a hardware-software tool for implementing control algorithms. Classification of microprocessors. Features of the architecture and software of digital controllers. The Architecture of von Neumann and Harvard Architecture. Examples of onboard microprocessor control systems.

Topic 7. Hardware resources MCC-51 microcontrollers

The MCS-51 family of microcontrollers. Functional features of MC. Structure, functionality and hardware and software resources of the MCS-51 family of microcontrollers. Logical memory organization in MCS-51. The structure of the resident memory. Registry file, stack, special function register. External memory.

Topic 8. Instruction set and methods of addressing data in microcontrollers

Instruction set and principles of microcontroller MCS-51 programming. Instruction formats and data addressing modes. Features of reading and executing commands. The structure of the program, the means of implementing the structural units of the program.

Topic 9. Forming and using of the stack

Stack as an area of memory with the FILO access protocol. Hardware and software support for the FILO protocol. Use stack when executing subroutines.

Topic 10. Implementation of peripheral functions in microcontrollers. Input / Output Ports of MCS-51 microcontroller.

Implementation of peripheral functions in microprocessor systems. Ports of parallel and serial I/O data. Data exchange protocols between processor and external devices. Input/Output in MC MCS-51. Interaction of MCS-51 with external memory. Characteristics of peripheral units in the MCS-51 and the principles of their interaction with the processor. Connecting data display devices.

Topic 11. Structure and use of timers in microcontrollers

Realization of time functions using timers of digital controllers. Structure, operating modes, program adjustment of timers in microcontroller MCS-51. Calculation of parameters of timers adjustment.

Topic 12. Serial port UART in microcontrollers

Structure and principles of using the UART Serial Port containing in MCS-51 microcontrollers. Calculation of operating modes and software setting of the UART.

Topic 13. Interrupts processing in microcontrollers

The concept of interrupting the program and the principles of interrupt processing in microprocessor systems. The structure and functions of the interrupt controller. Interrupt handling in microcontrollers MCS-51. Principles of software adjustment of interrupt controller.

Module 3. Controllers with bus-based architecture

Semantic modulus 3. Controllers with bus-based architecture

Topic 14. Digital controllers with bus-based architecture

Bus-based architecture as the basic principle of constructing computing devices. Bus resources of microcontrollers. Minimal and bus-based configuration of the microcontroller system. The structure of the

technical requirements for designing a digital controller. Buffer cascade construction. Diagram of forming of control signals. Distribution of the address space of the controller and the method of calculation of address selectors.

Topic 15. Analog-digital interfaces of microprocessor systems

Typical structures of channels of analog-digital input-output units. Basic functional circuits of analog-to-digital converters (ADCs) and digital analog converters (DACs). Characteristics of data exchange protocols. Examples of hardware and software implementation of channels of analog-to-digital conversion.

Topic 16. Up-to-date models of microcontrollers of the MCS-51 family

An overview of modern models MC MC-51. Structure and usage of timers T2 and WDT. Interface SPI for loading program to MC.

Module 4. Input and output of analog signals based on modulators

Semantic modulus 4. Input and output of analog signals based on modulators

Topic 17. Incoming of analog signals to MC on the base of frequency pulse modulation (FPM).

Hardware implementation of incoming frequency pulse modulators (FPM). Hardware-software measurement of the pulse frequency and pulse period at the MC. Mathematical description of measuring channel with FPM. Calculation of the value of measured physical parameter.

Topic 18. Incoming of analog signals to MC on the base of pulse-width modulation (PWM).

Hardware implementation of incoming PWM. Hardware-software measurement of the pulse duration on the MC. Mathematical description of measuring channel with PWM. Calculation of the measured physical parameter value. Hardware implementation of output PWM. Software implementation of output WM impulses. Smoothing of WM-signals and polarity formation.

Тема 19. Analog-to-digital and digital-to-analog converter with serial interface.

Using in-system serial interfaces. Integrated ADC with serial interface. Integrated DAC with serial interface. Hardware and software interfacing of ADC and DAC with MC.

Module 5. Basics of Designing Digital Controllers

Semantic modulus 5. Basics of Designing Digital Controllers

Topic 21. Techniques for designing digital controllers.

The structure of the technical requirements for designing a digital controller. Basic system parameters and requirements for the controller. Stages of designing the controller. Assessment of the required resources of the MC system. Selection of the controller configuration according to the structure of the control system. Calculation of resources of storage devices. Distribution of the address space (AP) of the microprocessor system. Fundamentals of the choice and calculation of analog-digital and digital-to-analog converters of various types.

Topic 21. Architecture and Programming Principles of the MC of the AVR family.

Features of the architecture and classification of the MC of the AVR family. Scope of AVC AVC. Structure of the kernel and register model. Nomenclature and structure of peripheral devices in the AVR MC. Overview of the instruction set and principles of software development.

Тема 22. Features of the use of controllers in digital ACS.

Implementation of the sampling period based on program delays. Using timers to form a sampling period of the control loop execution. The structure of the program for MC when using timers and interrupts. Practical implementation of the control laws.

4. Course structure

Semantic modules and topics	Hours									
	Full-time					Part-time				
	total	among them				total				
		lect.	tutor	labs	indep.		l.	t.	l.	i.
1	2	3	4	5	6	7	8	9	10	11
Module 1										
Semantic modulus 1. Circuitry of digital units										
Topic 1. Introduction to discipline «Microcontrollers»	1	1	–	–	–					
Topic 2. Basic logic functions and logic gates. Design of combinational circuits	11	3	–	4	4					
Topic 3. Integrated combinational discrete devices	12	4	–	4	4					
Topic 4. Discrete devices with memory.	16	4	–	–	12					
Topic 5. Storage integrated circuits	6	2	–	–	4					
Total for semantic modulus 1	46	14		8	24					
Module 2										
Semantic modulus 2. Architecture and programming of single-chip microcontrollers of the MCS-51 family										
Topic 6. Classification of microprocessors. Features of the architecture and software of digital controllers	6	2		–	4					
Topic 7. Hardware resources MCS-51 microcontrollers	6	2		–	4					
Тема 8. Instruction set and methods of addressing data in microcontrollers	20	2		6	12					
Тема 9. Forming and using of the stack	6	2		–	4					
Topic 10. Implementation of peripheral functions in microcontrollers. Input / Output Ports of MCS-51 microcontroller	10	2		4	4					
Тема 11. Structure and use of timers in MC	10	2		4	4					
Тема 12. Serial port UART in microcontrollers	8	2		2	4					

1	2	3	4	5	6	7	8	9	10	11
Topic 13. Interrupts processing in microcontrollers	10	2		4	4					
Total for semantic modulus 2	76	16		20	40					
Module 3										
Semantic modulus 3. Digital controllers with bus-based architecture										
Topic 14. Digital controllers with bus-based architecture	10	2	–	4	4					
Topic 15. Analog-digital interfaces of microprocessor systems	14	4	–	6	4					
Topic 16. Up-to-date models of microcontrollers of the MCS-51 family	4	2	–	–	2					
Total for semantic modulus 3	28	8	–	10	10					
Total for modules 1-3 (semester 6)	150	38	–	38	74					
Module 4										
Semantic modulus 4. Input and output of analog signals based on modulators										
Topic 17. Incoming of analog signals to MC on the base of frequency pulse modulation (FPM).	16	2	–	4	6					
Topic 18. Incoming of analog signals to MC on the base of pulse-width modulation (PWM).	14	4	–	4	6					
Topic 19. Analog-to-digital and digital-to-analog converters with serial interface	10	2	–	–	8					
Total for semantic modulus 4	36	8	–	8	20					
Module 5										
Semantic modulus 5. Basics of Designing Digital Controllers										
Topic 20. Techniques for designing digital controllers	43	2		6	20					
Topic 21. Architecture and Programming Principles of the MC of the AVR family	12	2		–	10					
Topic 22. Features of the use of controllers in digital ACS	29	3		16	10					
Total for semantic modulus 5	84	7		22	40					
Total for modules 4 and 5 (semester 7)	105	15		30	60					
Course total	255	53		68	134					

5. Topics of seminar classes

№ a/o	Topic name	Hours	
		Full-time	Part-time
1	Not appointed	–	–
2		–	–

6. Topics of tutorials

№ a/o	Topic name	Hours	
		Full-time	Part-time
	Not appointed		

7. Topics of lab classes

№ a/o	Topic name	Hours	
		Full-time	Part-time
1	Minimization of logic functions. Research of logic units and simple logic circuits of a combinational type	4	–
2	Construction and research of the application of multiplexer and decoder circuits	4	–
3	Construction and research of the application of binary counter circuits	6	–
4	Structure and principles of work with the integrated environment MCStudio for MC software development. Basics of program development in the C language for MC of the MCS-51family	4	–
5	Input and output data through parallel ports of MC-system. Realization of the algorithm of the finite automate on the basis of the table of states	4	–
6	Hardware-software measurement of the frequency of external impulses on the basis of MC timers	4	–
7	Programming the MC response to external events and hardware-software formation of time intervals based on timers	6	–
8	Development and testing of a program that control the operation of analog-to-digital converter and sends data to PC	6	–
9	Measurement of the physical parameter represented by frequency-modulated pulses	4	–
10	Measurement of the physical parameter represented by width-modulated pulses	4	–
11	Programming of the protocol of bilateral data exchange	6	–
12	Experimental reception of the magnitude-frequency response of the object of automatic control with the help of a controller	8	–
13	Programming of the digital regulator for a closed-loop control system	8	–
	Total hours	68	

8. Self-study (unaided) work

№ a/o	Topic name	Hours	
		Full-time	Part-time
1	Structure and aims of studying of the discipline «Microcontrollers»	–	–
2	Basic logic functions and logic gates. Design of combinational circuits (Topic 2)	4	–
3	Integrated combinational discrete devices (Topic 3)	4	
4	Discrete devices with memory (Topic 4)	8	
5	Storage integrated circuits (Topic 5)	8	
6	Classification of microprocessors. Architecture and software of digital controllers (Topic 6)	4	
7	Hardware resources of MCS-51 microcontrollers (Topic 7)	4	
8	Instruction set and methods of addressing data in microcontrollers (Topic 8)	4	
9	Forming and using of the stack. (Topic 9)	4	
10	Implementation of peripheral functions in microcontrollers. Input / Output Ports of MCS-51 microcontroller. (Topic 10)	4	
11	Structure and use of timers in MC. (Topic 11)	4	
12	Serial port UART in microcontrollers. (Topic 12)	4	
13	Interrupts processing in microcontrollers (Topic 13)	4	
14	Digital controllers with bus-based architecture. (Topic 14)	4	
15	Analog-digital interfaces of microprocessor systems. (Topic 15)	4	
16	Up-to-date models of microcontrollers of the MCS-51 family (Topic 16)	2	
17	Incoming of analog signals to MC on the base of frequency pulse modulation (FPM). (Topic 17)	6	
18	Incoming of analog signals to MC on the base of pulse-width modulation (PWM). (Topic 18)	6	
19	Analog-to-digital and digital-to-analog converters with serial interface. (Topic 19)	8	
20	Techniques for designing digital controllers. (Topic 20)	20	
21	Architecture and Programming Principles of the MC of the AVR family. (Topic 21)	10	
22	Features of the use of controllers in digital ACS. (Topic 22)	10	
	Total hours	**134**	

9. Individual assignments

№ a/o	Topic name	Hours
1	Not appointed	

10. Teaching methods

Lectures delivering, conducting lab classes, individual consultations (if necessary), independent work of students with tutorials issued by the department (learning the manuals).

11. Forms of control

Current control tests in form of lab report submission, final examination.

12. Assignment of grade points obtaining by a student (credit passed)

Семестр 6

Current tests and unaided work											Summative test (examination) due to refusing the received current points and intent taking the exam if allowed
Semantic Modulus 1 (weight)			Semantic Modulus 2 (weight)				Semantic Modulus 3 (weight)			Grade points total	
T2	**T3**	**T4**	**T8,T9**	**T10, T12**	**T11**	**T13**	**T14**	**T15**	**T16**	**100**	**100**
10	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**		

T2, T3, …, T15 – topics included to the modulus

Семестр 7

Current tests and unaided work							Summative test (examination) due to refusing the received current points and intent taking the exam if allowed
Semantic Modulus 4 (weight)			Semantic Modulus 5 (weight)			Grade points total	
T17	**T18**	**T19**	**T20**	**T21**	**T22**	**100**	**100**
10	**10**	**10**	**20**	**20**	**30**		

T17-T21 – topics included to the modulus

Rating scale: national and ECTS

Total points at all types of educational activity	**Mark in ECTS**	**Mark in national scale**	
		for exam, term paper defense, practice	**for passing**
90 – 100	**A**	**Excellent**	**passed**
83 – 89	**B**	**Good**	
75 – 82	**C**		
68 – 74	**D**	**Satisfactory**	
60 – 67	**E**		
1 – 59	**FX**	**Unsatisfactory with possibility of the re-examination**	**not passed with possibility of re-passing**

13. Methodological support

All methodological support is located as shared resource at department 301 server. Author of all documents is V. Dzhulgakov, docent of dept. 301. Path for downloading: R:\materials\Microcontrollers

1. Conspectus of the discipline «Microcontrollers». 2017.
2. Points and problems for solving to labs in semester 6. 2017.
3. Points and problems for solving to labs in semester 7. 2017.
4. System software of the UEMC-2. User's Manual. 2010 p.

14. Recommended reading

Basic

1. Parab, J., Shinde, S.A., Shelake, V.G., Kamat, R.K., Naik, G.M. Practical Aspects of Embedded System Design using Microcontrollers. Springer Springer Netherlands, 2008. – 150 p.
2. Parab, J., Shelake, V.G., Kamat, R.K., Naik, G.M. Exploring C for Microcontrollers. A Hands on Approach. – Springer, 2007. – 157 p.
3. Susnea, I., Mitescu, M. Microcontrollers in Practice. – Springer, 2005. 251 p.
4. Trevennor, A. Experimenting with AVR Microcontrollers. – Appress, 2014. – 197 p.

Complementary reading

1. Фурман І.О., Малиновський М.Л., Джулгаков В.Г. та ін. Мікроелектронні засоби програмного керування / Під заг. Ред. І.О. Фурмана: Підручник для студентів ВНЗ. Харків: Факт, 2007. – 486 с.
2. Угрюмов Е.П. Цифровая схемотехника.– СПб.: БХВ-Петербург, 2001. – 528 с.
3. Водовозов А. М. Микроконтроллеры для систем автоматики: учебное пособие / А.М. Водовозов. М.: Инфра-Инженерия, 2016. – 164 с.
4. Проектування цифрових контролерів. / В.Г. Джулгаков, К.І. Руденко. – Навч. посібник. – Х.: Нац. аерокосм. ун-т «Харьк. авіац. ін-т», 2008 – 100 с.
5. Ключев А.О., Ковязина Д.Р., Кустарев П.В., Платунов А.Е. Аппаратные и программные средства встраиваемых систем. Учебное пособие. – СПб.: СПбГУ ИТМО, 2010. – 290 с.

14. Інформаційні ресурси

1. Сайт кафедри 301: **k301.info**.
2. Офіційний сайт провідного виробника мікроконтролерів: www.atmel.com