SYLLABUS

1. Program information

1.1 Higher education institution	Technical University of Cluj-Napoca
1.2 Faculty	Faculty of Electronics, Telecommunications and Information Technology
1.3 Department	Bases of Electronics
1.4 Field of study	Electronic engineering, telecommunications and information technologies
1.5 Cycle of study	Bachelor of Science
1.6 Study program / Qualification	Electronic engineering, telecommunications and information technologies/ Engineer
1.7 Form of education	IF – full-time education

2. Course information

2.1 Course title	Systems with digital integrated circuits			Course code	27.00
2.2 Course coordinator	*Assoc.prof. Paul FARAGÓ, Ph.D. – Paul.FARAGO@bel.utcluj.ro*				
2.3 Seminar/ laboratory/ project/ practical activity coordinator	*Assoc.prof. Paul FARAGÓ, Ph.D. – Paul.FARAGO@bel.utcluj.ro* *Assoc.prof. Mihaela CÎRLUGEA, Ph.D. – Mihaela.Cirlugea@bel.utcluj.ro*				
2.4 Year of study	II	2.5 Semester	2	2.6 Type of assessment	E
2.7 Course status	Formative category				DD
	Optionality				DOB

3. Estimated total time

3.1 Hours per week	4	of which:	3.2 Lecture	2	3.3 Seminar	0	3.3 Laboratory	1	3.3 Project	1	3.3 Practical training	0
3.4 Hours per semester	56	of which:	3.5 Lecture	28	3.6 Seminar	0	3.6 Laboratory	14	3.6 Project	14	3.3 Practical training	0

3.7 Time distribution (hours per semester) for individual study and assessment:	
(a) Assessment	3
(b) Study using textbook, course materials, bibliography, and notes	21
(c) Additional documentation in the library, on specialized electronic platforms, and in the field	14
(d) Preparation for seminars/laboratories, assignments, reports, portfolios and essays	28
(e) Tutoring	3
(f) Other activities	-

3.8 Total hours of individual study and assessment (sum of (3.7(a)...3.7(f))	69
3.9 Total hours per semester (3.4+3.8)	125
3.10 Number of credits	5.0

4. Prerequisites (where applicable)

4.1 curriculum	Digital Integrated Circuits, Electronic Devices, Fundamental Electronic Circuits, Passive Components and Circuits.
4.2 competencies	Binary arithmetic, Boolean algebra, and logic minimization Analysis and design of combinational and sequential circuits Electrical circuit analysis using basic circuit laws and theorems Frequency behavior and frequency response of electronic circuits Ability to model, simulate, and verify digital circuits using a hardware description language.

5. Requirements (where applicable)

5.1. for the development of the lecture	Lecture room equipped with a computer, a multimedia projector (with connectivity hub for external laptops), projection screen, whiteboard/blackboard, and Internet access.
5.2. for the development of the seminar/ laboratory/ project	Laboratory equipped with desktop computers, FPGA development boards, electronic measurement instruments, multimedia projector (with connectivity hub for external laptops), projection screen, whiteboard/blackboard, and Internet access.

6. Specific competencies acquired

Professional competencies	C1 Use of fundamental elements related to electronic devices, circuits, systems, instrumentation and technology C1.1 Description of the operation of electronic devices and circuits and of the fundamental methods for measuring electrical quantities C1.2 Analysis of low-/medium-complexity electronic circuits and systems for their design and measurement C1.3 Diagnosis/troubleshooting of electronic circuits, equipment and systems C1.4 Use of electronic instruments and specific methods to characterize and evaluate the performance of electronic circuits and systems C1.5 Design and implementation of low-/medium-complexity electronic circuits using CAD-CAM technologies and standards in the field. C2 Application of basic methods for signal acquisition and processing C2.1 Time-domain, spectral and statistical characterization of signals C2.2 Explanation and interpretation of signal acquisition and processing methods C2.3 Use of simulation environments for signal analysis and processing C2.4 Use of specific methods and instruments for signal analysis C2.5 Design of elementary functional blocks for digital signal processing with hardware and software implementation. C3 Application of basic knowledge, concepts and methods related to computer-system architecture, microprocessors, microcontrollers, programming languages and techniques

Professional competencies	C3.1 Description of the operation of a computer system, of the basic principles of general-purpose microprocessor and microcontroller architecture, and of the general principles of structured programming C3.2 Use of general-purpose programming languages and languages specific to microprocessor and microcontroller applications; explanation of the operation of automatic control systems using these architectures and interpretation of experimental results C3.3 Solving concrete practical problems that include elements of data structures and algorithms, programming and the use of microprocessors or microcontrollers C3.4 Development of programs in a general-purpose and/or specific programming language, from requirements specification to execution, debugging and interpretation of the results in relation to the processor used C3.5 Implementation of projects involving hardware components (processors) and software (programming). C4 Design and use of low-complexity hardware and software applications specific to applied electronics C4.1 Definition of the concepts, principles and methods used in: computer programming, high-level and specific languages, CAD techniques for creating electronic modules, microcontrollers, computer-system architecture, programmable electronic systems, graphics and reconfigurable hardware architectures C4.2 Explanation and interpretation of the requirements specific to hardware and software structures in the fields of: computer programming, high-level and specific languages, CAD techniques for creating electronic modules, microcontrollers, computer-system architecture, programmable electronic systems, graphics and reconfigurable hardware architectures C4.4 Use of appropriate performance criteria to evaluate, including by simulation, the hardware and software of dedicated systems or service activities using microcontrollers or low-/medium-complexity computer systems. C5 Application of basic knowledge, concepts and methods from: power electronics, automatic systems, electrical energy management and electromagnetic compatibility C5.2 Qualitative and quantitative interpretation of the operation of circuits in the fields of: power electronics, automatic systems, electrical energy management, medical electronics, automotive electronics and consumer goods; analysis of operation from the standpoint of electromagnetic compatibility C5.3 Preparation of technical specifications, installation and operation of equipment in the fields of applied electronics: power electronics, automatic systems, electrical energy management, medical electronics, automotive electronics and consumer goods C5.4 Evaluation, based on technical quality and environmental impact criteria, of equipment in the fields of applied electronics: power electronics, automatic systems, electrical energy management, medical electronics, automotive electronics and consumer goods C5.5 Design, using established principles and methods, of low-complexity subsystems in the fields of applied electronics: power electronics, automatic systems, electrical energy management, medical electronics, automotive electronics and consumer goods.
Transversal competencie	

7. Expected learning outcomes

Knowledge	- The student/graduate explains and interprets theoretical and experimental results in mathematics, physics, chemistry, economics, technical drawing and computer science. - The student/graduate describes, identifies and summarizes elementary concepts and methods related to electronic devices, circuits and instrumentation, as well as their application in concrete problems.
Skills	- The student/graduate applies evaluation criteria and methods for identifying, modelling, experimenting, analysing and qualitatively and quantitatively assessing phenomena and processes specific to the fundamental field, including by using digital technologies. - The student/graduate designs solutions, in compliance with relevant standards, for medium-complexity engineering problems that meet specified needs, while observing requirements related to public health, safety, welfare, environment, sustainability and economic factors, as well as other specific constraints. - The student/graduate uses fundamental methods for measuring electrical quantities and assesses electronic devices and circuits, as well as linear and digital integrated circuits of low/medium complexity. - The student/graduate designs, measures, evaluates performance, diagnoses and troubleshoots functional blocks composed of low/medium-complexity electronic devices and/or circuits.
Responsibility and autonomy	- The student/graduate carries out project management processes in electronics, telecommunications and information technologies, taking on different team roles and clearly and concisely describing the results, both orally and in writing.

8. Course objectives (based on the grid of specific competencies acquired)

8.1 General objective of the course	Provide students with the theoretical foundations and practical design principles of CMOS-based digital integrated circuits and systems, enabling them to understand, analyze, design, implement, and evaluate low- and medium-complexity digital electronic systems, considering timing, power, and implementation constraints.
8.2 Specific objectives	Develop an understanding of CMOS device operation and the transistor-level implementation of logic gates and sequential circuits. Familiarize with timing characteristics of digital integrated circuits, including propagation delay, setup and hold times, clock distribution and synchronization. Develop the ability to analyze and compare alternative digital circuit implementations with respect to speed, power consumption and area. Introduce the organization and operation of pulse generation and processing circuits, arithmetic circuits, memories, programmable logic devices, and FPGA architectures. Develop practical skills in modeling, simulation, verification, and implementation of digital systems using CAD and HDL tools.

	Design and evaluation of low- and medium-complexity digital subsystems while considering engineering standards, sustainability, and good design practices.

9. Contents

9.1 Lecture	No. of hours	Teaching methods	Remarks
1. CMOS technology and digital abstraction: Digital-system abstraction levels; reasons for using CMOS; MOSFET basics; NMOS and PMOS devices; complementary operation; area, speed, energy and power as design criteria.	2	Lecture and explanation; heuristic conversation; demonstration and exemplification; problem-based learning; guided exercises; case studies; formative assessment and feedback.	Teaching supported by multimedia presentations, a projector, and the blackboard. A dedicated Microsoft Teams team and its associated SharePoint space are used for communication and distribution of electronic materials, including lecture slides, handouts, solved examples, assignments, and supplementary resources. Microsoft OneNote is used when appropriate as a digital whiteboard.
2. The CMOS inverter: CMOS inverter structure and operation; voltage-transfer characteristic; switching threshold; noise margins; transistor sizing; rise/fall asymmetry; capacitive loading; propagation and contamination delay; dynamic, short-circuit and leakage power.	2		
3. Static CMOS logic gates: Pull-up and pull-down network design; NAND and NOR gates; complex static CMOS gates; series and parallel transistor networks; transistor sizing; fan-in and fan-out; delay and power trade-offs.	2		
4. Pass-transistor and transmission-gate logic: NMOS and PMOS pass transistors; threshold-voltage effects; transmission gates; comparison with static CMOS; transistor-level multiplexers and demultiplexers; XOR structures; area, delay and signal-integrity trade-offs.	2		
5. CMOS latches, flip-flops and clocked-logic timing: Static and transmission-gate latches; transparent and opaque operating phases; master–slave and edge-triggered flip-flops; setup and hold constraints; clock-to-output delay; clock overlap and race conditions; clock skew and jitter; maximum operating frequency; metastability and two-flip-flop synchronizers.	2		
6. Register design, low-power control and FSM implementation: Flip-flop arrays and register organization; parallel enable; data gating and clock gating; reset and initialization strategies; asynchronous assertion and synchronous release; state-register implementation; binary and one-hot state encoding; registered outputs; safe initialization and recovery; timing, area and power trade-offs.	2		
7. Synchronous counters and sequence generators: Counter implementation using state registers and next-state	2		

9.1 Lecture	No. of hours	Teaching methods	Remarks
combinational logic; synchronous modulo-N counters; terminal-count logic; ring and Johnson counters; linear-feedback shift registers; pseudo-random sequence generation; illegal states and safe recovery.			
8. Asynchronous counters and ripple timing: Ripple-counter operation; asynchronous frequency division; accumulated propagation delay; decoding glitches; ripple-counter capacity extension; comparison between synchronous and asynchronous counters; application limitations.	2		
9. Pulse generation and signal conditioning: Schmitt-trigger inverter; hysteresis and robust switching; switch debouncing; edge and pulse detection; monostable and astable circuits; digital pulse shaping; ring oscillators; clock and test-signal generation.	2		
10. Fundamental arithmetic building blocks: Half and full adders; ripple-carry adders; subtractors and adder–subtractor structures; magnitude comparators; unsigned and signed arithmetic; two's-complement representation; carry, borrow and signed-overflow detection.	2		
11. Advanced arithmetic circuits and datapaths: Carry-lookahead and other fast-adder principles; arithmetic-logic-unit structures; incrementing, shifting and data-routing circuits; add-and-shift multiplication; multiplier–accumulator structures; area, latency, throughput and power trade-offs.	2		
12. Memory technologies and organization: Classification of volatile and non-volatile memories; ROM, PROM, EPROM, EEPROM and Flash memory; RAM, SRAM and DRAM; memory-cell and array organization; address decoding; read and write operations; access time, cycle time, capacity, power consumption and data retention.	2		
13. Memory expansion and memory-based digital systems: Memory capacity and word-width expansion; address-space organization and bank selection; memory interfacing and timing; register files; FIFO queues, LIFO stacks; read/write; ROM-based finite-state machines; memory-based sequence, pattern and signal generators.	2		
14. Programmable logic and system implementation: Evolution from PLA and PAL devices to CPLDs and FPGAs; programmable logic arrays and macrocells; FPGA LUT–flip-flop fabric; routing resources; carry chains and block RAM;	2		

9.1 Lecture	No. of hours	Teaching methods	Remarks
mapping of combinational logic, FSMs, counters and memories; timing, power and implementation constraints.			

Bibliography:
1. Sorin Hintea, Gabor Csipkes, Doris Csipkes, Paul Farago, Mihaela Cirlugea – Digital Integrated Circuits. Editura Casa Cărţii de Ştiinţă, Cluj-Napoca, 2017
2. Gabor Csipkes, Doris Csipkes, Sorin Hintea, Mihaela Cîrlugea - "Circuite integrate digitale: culegere de probleme", UT Press 2011
3. J. Wakerly – Digital Design, Principle & Practices, Prentice Hall, 1999.
4. H. Kaeslin – Digital Integrated Circuit Design From VLSI Architecture to CMOS Fabrication, Cambridge University Press, 2008.
5. Baker, R. Jacob – CMOS: Circuit Design, Layout, and Simulation. Revised 2nd ed. IEEE Press and Wiley-Interscience, 2008. ISBN 978-0-470-22941-5
6. Willy M. C. Sansen – Analog Design Essentials, Springer, 2006.

9.2 Seminar /laboratory /project /practical training	No. of hours	Teaching methods	Remarks
Laboratory		Demonstration and guided experimentation; practical exercises; problem-solving; simulation-based analysis; project-based learning; teamwork; formative assessment and feedback.	Laboratory activities use LTspice for transistor-level simulation. Project activities use HDL and FPGA development boards. Materials are provided through Microsoft Teams and SharePoint.
1. CMOS inverter	2		
2. Static CMOS logic gates	2		
3. Pass-transistor and transmission-gate circuits	2		
4. Registers and synchronous counters	2		
5. Asynchronous counters	2		
6. Memory cells and small memory-based circuits	2		
7. Laboratory assessment and make-up session	2		
Project			
1. Project definition and requirements	2		
2. Counter and decoder design for pattern generation	2		
3. Behavioral description of finite-state machines	2		
4. Finite-state-machine design examples	2		
5. Peripheral interfaces and signal conditioning	2		
6. System integration and verification plan	2		
7. Project presentation and assessment; make-up session	2		

Bibliography:
1. Paul Farago, Botond Kirei, Gabor Csipkes, Sorin Hintea – Descrierea in VHDL a sistemelor cu circuite integrate digitale - Indrumator de Proiectare si Simulare. Editura U.T.PRESS, Cluj-Napoca, 2014
2. H. Kaeslin – Digital Integrated Circuit Design From VLSI Architecture to CMOS Fabrication, Cambridge University Press, 2008.

9.2 Seminar /laboratory /project /practical training	No. of hours	Teaching methods	Remarks
3. ROTH, Charles H., Jr.; JOHN, Lizy Kurian. *Digital Systems Design Using VHDL*. 2nd ed. Thomson Learning, 2008. ISBN 978-0-534-38462-3. 4. JOHN, Lizy Kurian; ROTH, Charles H.; LEE, Byeong Kil. Digital Systems Design Using Verilog. 1st ed. Cengage Learning, 2015. ISBN 978-1-305-12074-7.			

10. Alignment of the course contents with the expectations of the epistemic community, professional associations, and representative employers in the field related to the program

The course content and the teaching-learning-assessment methods are aligned with the current requirements of the Electronics, Telecommunications, and Information Technology Engineering field, considering the expectations of the academic and professional community, representative employers, as well as the national quality assurance standards in higher education. The course helps prepare students in line with employer expectations and the quality requirements set for engineering study programs.

11. Assessment

Activity type	11.1 Assessment criteria	11.2 Assessment methods (and type of assessment: continuous/ summative)	11.3 Weight in final grade
11.4 Lecture	Understanding and correct use of the fundamental concepts of CMOS digital circuits and systems; analysis of circuit operation; interpretation of timing, power and implementation constraints; application of design methods to arithmetic circuits, sequential circuits, memories and programmable logic systems.	Summative assessment – written examination (E) consisting of theoretical questions and design, analysis and calculation problems.	E: 50%
11.5 Seminar/ Laboratory/ Project /Practical activity	**Laboratory**: Correct implementation and simulation of the assigned circuits; interpretation of simulation and experimental results; use of LTspice for transistor-level circuit analysis; completion of laboratory activities and reports. **Project**: Correct formulation of system requirements; structural and behavioral HDL description; functional decomposition and FSM design; integration and verification of the digital system; implementation on an FPGA	Laboratory (L): Continuous assessment – assessment of practical laboratory work, simulation results, reports and laboratory test. Project (P): Continuous assessment – evaluation of project stages, HDL implementation, simulations, verification plan, FPGA demonstration and final presentation.	L: 20% P: 30%

	development board; quality of documentation and presentation; ability to explain and justify design decisions.		

11.6 Minimum performance standard

Written examination – E ≥ 5, the minimum requirements for obtaining grade 5 are:

- explain the fundamental operating principles of CMOS digital circuits;
- analyze and design low- or medium-complexity digital functional blocks;
- interpret basic timing and power characteristics;

Attendance at all laboratory and project activities is compulsory. All required practical activities must be completed.

Laboratory: L ≥ 5 the minimum requirements for obtaining grade 5 are:

- perform transistor-level simulations and correctly interpret the obtained results

Project: P ≥ 5 the minimum requirements for obtaining grade 5 are:

- describe, simulate, verify and implement a digital system using HDL and an FPGA development board;
- identify and correct basic circuit, simulation and implementation errors

If E ≥ 5, L ≥ 5 and P ≥ 5, then the final mark for the discipline is calculated with the expression

$$0.5 \cdot E + 0.2 \cdot L + 0.3 \cdot P$$

Completion date:	**Course coordinators**	**teaching rank, title First name LAST NAME**	**Signature**
23.06.2026	Lecture	Assoc.prof. Paul FARAGÓ, Ph.D.	
	Applications	Assoc.prof. Paul FARAGÓ, Ph.D.	
		Assoc.prof. Mihaela CÎRLUGEA, Ph.D.	

Approval of the Head of the Department coordinating the course, only if this differs from the department organizing the study program	Head of the Department

Date of approval by the Council of the Department of Bases of Electronics 26.06.2026	Head of the Bases of Electronics Department Prof. Sorin HINTEA, Ph.D.
Date of approval by the Council of the Faculty of Electronics, Telecommunications and Information Technology 30.06.2026	Dean, Prof. Ovidiu-Aurel POP, Ph.D.