(*faculty stamp*)

COURSE DESCRIPTION

1. Course title: ADVANCED CONTROL	**2. Course code**
3. Validity of course description: 2016/2017	
4. Level of studies: MSc programme	
5. Mode of studies: intramural studies	
6. Field of study: MACROCOURSE	(FACULTY SYMBOL)
7. Profile of studies: general	
8. Programme: Automatic control	
9. Semester: 1	
10. Faculty teaching the course: Institute of Automatic Control, Rau1	
11. Course instructor: prof. zw. dr hab. inż. Ryszard Gessing	
12. Course classification: programme courses	
13. Course status: compulsory	
14. Language of instruction: English	
15. Pre-requisite qualifications: Control Fundamentals, Fundamentals of Signal Processing, Optimization and Decision Making, Calculus and Differential Equations. It is assumed that the student has the basic knowledge concerning analysis and design automatic control systems, as well as solutions of nonlinear differential equations, signal processing problems and methods of optimization.	
16. Course objectives: Nonlinear control systems, being a subject of the course, need for their analysis and design advanced computer tools. This is related with the fact that, though the nonlinear systems are significantly richer in phenomena, the methods of their analysis and design are less elaborated than those of linear systems. Effective usage of computer tools is possible only then when one has an appropriate knowledge of advanced nonlinear control. Therefore in the course a big effort is made to give a good foundation of nonlinear control knowledge. This is the main objective of the course.	
17. Description of learning outcomes:	

Nr	Learning outcomes description	Method of assessment	Teaching methods	Learning outcomes reference code
W1	The student knows basic types of nonlinearities that can be found in automatic control systems and their influence on control quality	EP	WT, WM	K_W01, K_W04, K_W06, K_W14
W2	The student knows basic methods of analysis of nonlinear control systems, with emphasis on their stability and quality	EP	WT, WM	K_W12, K_W13
W3	The student knows the limitations arising from nonlinear phenomena in control systems.	EP	WT, WM	K_W12
W4	The students knows the types of switching control systems and their properties, including sliding mode control, and has rudimentary knowledge of optimal and adaptive control systems.	EP	WT, WM	K_W12, K_W13, K_W14, K_W20
U1	The student can analyze nonlinear control systems and design them.	EP, SP,	C, L	K_U08, K_U09, K_U16, K_U17
U2	The student can perform simulation-based analysis of a nonlinear control system using MATLAB-SIMULINK software.	SP, CL	C, L	K_U07, K_U09, K_U18, K_W15
U3	The student is able to use nonlinearities to improve the quality of a control system (antiwindup, saturation).	SP, CL	C, L	K_U07, K_U08, K_U16, K_U21

U4	The student is able to use CAD software in design of nonlinear control systems	CL	C, L	K_U11
K1	The student can independently make decisions concerning the choice of acceptable and the best solutions.	CL, PS	L	K_K04, K_K05
K2	The student can present the proposed solution and justify its choice and provide arguments proving its quality.	OS	L	K_K02, K_K05

18. Teaching modes and hours

Lecture / BA /MA Seminar / Class / Project / Laboratory

Lecture: 30 h./ Class: 30 h/ Lab: 30h

19. Syllabus description:

Lectures:

Nonlinear systems. Models of nonlinear systems - nonlinear differential equations. Characteristics of nonlinear elements. Nonlinearities, their description and characteristics. Examples of nonlinear elements. Phase plane analysis. Equations of phase trajectories, phase portrait. Derivation of phase trajectories: - method of isoclines; - solution of phase trajectory equation. Properties of phase trajectories. Singular points and trajectories. Method of describing function. Definition of describing function - comparison with frequency response. Examples of describing functions. Condition of free oscillations. Determination of oscillation parameters. Application to stability analysis of control systems. Indirect and direct Lyapunov methods. Lyapunov definition of stability and asymptotic stability. Local stability, indirect Lyapunov method. Determination of equilibrium points. Global stability, direct Lyapunov method. Determination of stability region (domain of attraction). Analysis of discrete-time systems. The case when nonlinearity appears - in continuous-time part of the system; - in discrete-time part of the system. Difference equations - determination of waveforms. Influence of nonlinearities on control quality, antiwindup solutions: analog, digital Control systems with dead zone relay. Voltage stabilization system and its phase plane analysis, determination of stability condition. System stabilization. Influence of delay. On-off relay control. System description - relation between switching frequency and oscillation magnitude. Influence of parameters on control waveforms. Decrease of oscillation magnitude. Sliding - mode control. Description of sliding mode control, sliding surface, chattering effect. Design of sliding mode control law. Example and results of simulations. Extremal control. Systems with plants having extremum. System with derivative sign examination. System with outside modulating signal, synchronic detection, approximate system description. The case of plant with multiple inputs. Adaptive control. Systems with gain scheduling. Model reference adaptive systems. Systems with current identification. Autotuning regulators. Optimal control. Maximum principle. Time-optimal control. Example of design.

Class exercises

Description of nonlinear systems. Phase plane method. Describing function method. Analysis of nonlinear systems stability using Lyapunov methods. Nonlinear discrete-time systems analysis. Relay control systems – phase plane approach. Sliding mode in relay systems. On-off relay control – time domain analysis. Vibratory linearization and control. Extremal control systems. Optimal control.

Laboratory

1. Phase plane method
2. Relay control I – phase plane analysis
3. Sliding control in relay systems
4. Relay control II – time domain analysis
5. Extremal control
6. Optimal Control – LQR problem

20. Examination: semester 1

21. Primary sources:

1. Advanced Control, draft text of the course written by R. Gessing, http://www.zsir.ia.polsl.pl/~dydaktyka/macro_ac/lecture/index.htm
2. Slotine J.J. and W. Li: Applied Nonlinear Control. Prentice Hall 1991.
3. Gessing R., Latarnik M., Skrzywan-Kosek A.: Zbiór zadań z teorii nieliniowych układów regulacji i sterowania, WNT, Warszawa 1981.

22. Secondary sources:

1. Goodwin G.C., S.F. Greabe and M.E. Salgado: Control system design. Prentice Hall, New Jersey 2001
2. Isidori A.: Nonlinear Control SYstems. Third Ed. Spronger Verlag,, London 1996
3. Phillips CL., Harbor R.D.: Feedback Control Systems (Third Edition) Prentice Hall, 1996

23. Total workload required to achieve learning outcomes

Lp.	Teaching mode :	Contact hours / Student workload hours
1	Lecture	30/30
2	Classes	30/20
3	Laboratory	30/30
4	Project	0/0
5	BA/ MA Seminar	0/0
6	Other	10/10
	Total number of hours	100/90

24. Total hours:190

25. Number of ECTS credits: 6

26. Number of ECTS credits allocated for contact hours: 3

27. Number of ECTS credits allocated for in-practice hours (laboratory classes, projects): 3

26. Comments:

Approved:

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(date, Instructor's signature)

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(*date , the Director of the Faculty Unit signature)*