STUDY PROGRAMME

N0714A270007
Automation and Instrumentation Engineering

State-exam topics for

specialization

AII
Automation and Industrial Informatics

Issued by

Department of Instrumentation and Control Engineering

Faculty of Mechanical Engineering

Czech Technical University in Prague

Technical Means of Automatic Control

1. Embedded systems, microcontroller, processor memories, busses (UART, USART, SPI, I2C).
2. I/O subsystem, digital and analog inputs/outputs, levels conversion, galvanic separation, counters, timers.
3. Asynchronous events service, ‘polling‘, interrupt, ‘watchdog ‘.
4. Methods of embedded systems programming (textual and graphical programming languages, ‘rapid prototyping‘).
5. Tools for specification and analysis of the control task with programmable logic controllers PLC, step diagram, state diagram, sequential function diagram SFC. Common states of industrial control systems and their specifications.
6. Programmable logic controllers. Principle of the operation, PLC scan cycle, hardware, PLC types, international standard EN 61131, basic concepts and structures. Open PLC platforms.
7. PLC programming languages according to EN 61131-3, common basics and concepts - data types, variables, POU, basics of 'Instruction List', 'Structured Text', 'Ladder Diagram' and 'Function Block Diagram' language. Algorithms for systematic programming of sequential and timed tasks.
8. Algorithms and architectures for control systems. Distributed control systems. Digital twin. Industry 4.0 principles. System integration, hierarchical organization of automation systems.
9. Radiation sources, classification and overview of types, spectral and directional characteristics, general and special properties of individual types.
10. Ideal black body radiation. Radiation of non-black body. Photometric and radiometric calculations.
11. Optical fibres, types, materials. Signal propagation via optical fibres, modes. Phenomena affecting the propagation of light in a fibre. Applications (illuminating, communication, measuring).
12. Radiation detectors, classification and their types overview. General and special properties of individual types. Applications (imaging, measuring).
13. Sensors of non-electric quantities - temperature, force, position, pressure, humidity, flow, liquid level.
14. P&ID diagrams - principles, examples and their applications.
15. Sensor fusion algorithms - noise suppression using multiple sensors, ‘voting‘ from multiple sensors, elimination of loss or sudden signal change, complementary filter.
16. Signal validation algorithms for sensors, self-validating sensors - detection and correction methods, time-frequency analysis, main components analysis.
17. Mechanical properties of electric drives - equation of motion, mechanical characteristics of load and motor.
18. Drives with DC motors - mathematical model of DC motor, control methods, feedback control.
19. Drives with induction motors - mathematical model of an induction machine, control without and with feedback.
20. Drives with synchronous motors with permanent magnets (PMSM), mathematical model of synchronous machine, feedback control.
21. Pneumatic circuits, pneumatic drives, valves, end position sensors, compressed air sources (quality classes, treatment units). Dimensioning, air consumption and its savings.
22. Pneumatic system dynamics, possible speeds and accelerations. Multidrive synchronization.
23. Hydrostatic mechanisms. Characteristics of hydraulic drives. Design of linear drives and schematic expression.
24. Hydraulic circuit structure of double-acting drive, two pump system for energy saving.

Theory and models of automatic control

1. Stability of linear systems and control loops (definition and meaning, stability criteria – based on roots of characteristic equation, Hurwitz and Nyquist criterion)
2. Laplace and Z transforms in analysis and solution of linear systems described by differential and difference equations (definition, properties, inverse transforms)
3. Definition and properties of linear state space models (decomposition to homogeneous and relaxed solution, state transition matrix, convolution integral, system modes)
4. Analysis of nonlinear systems (singular points in the state space, limit cycle, local and global stability)
5. Numerical methods and solvers for simulation of dynamical systems (explicit and implicit methods, time step adaptation, solver parameterization in Matlab-Simulink)
6. PID controller, implementation within closed loop, control saturation and antiwindup, implementation of derivative part, manual to automatic switching, two degree of freedom controller)
7. Multi-loop control systems, problems to be solved, targeted objectives (loops with auxiliary variables, internal model, cascade control, multi-variable control with mutually influenced variables).
8. State space model-based control methods – controllability, observability, state feedback control, state observer
9. Controller design in frequency and spectral domains – gain and phase margins, root-locus methods.
10. Robust controller design, H-infinity norm, sensitivity functions, mixed-sensitivity loop shaping of H-infinity optimal controller
11. Experimental determination and parameterization of characteristics of linear dynamical systems (step, impulse, and frequency responses)
12. Description of random variables and stochastic processes (probability characteristics, correlation, stationarity, ergodicity, white noise, power spectrum)
13. Parametric models of stochastic signals and systems
14. Identification of nonparametric models using correlation methods
15. Experimental identification of dynamic systems in the time domain using linear regression
16. Gradient-based optimization methods (Gradient-descent algorithm, Gauss-Newton method, Levenberg-Marquardt method), optimization step and convergence of iterative method
17. Linear (LP) and quadratic (QP) programming problems, feasible set of solutions, optimum, extremum of objective function, standard (equational) form, dual LP and QP problem
18. Dynamic programming, Bellman principle of optimality, Optimal control problem (classification based on criterion function type), necessary conditions for optimality
19. Linear-Quadratic (LQ) regulator, algebraic (matrix) Riccati equation, LQ control design based on linear matrix inequalities (LMI)
20. Model Predictive Control (MPC) algorithm, Receding Horizon Control (RHC), prediction and correction horizon, control input variable with reduced degrees of freedom

Engineering Informatics

1. Information theory and information system, definition and quantification of information, entropy, redundancy.
2. Signal and its transmission, communication physical layer, modulation, coding, transmission error detection, noise, channel and its capacity, industrial buses and their characteristics - CAN, MODBUS.
3. Computer networks (including industrial), properties, topology. ISO/OSI reference model, communication protocols of the layers. IP, TCP, UDP, SSL. Application data encapsulation on TCP/IP layers.
4. Object-oriented programming: class, object, principles. Advantages of object-oriented paradigm. Implementation of object-oriented technologies in programming languages. Work with memory, references, garbage collector. Communication among objects via messages and exceptions.
5. Subclasses and class inheritance. Loose typing and its purpose.
6. Cryptography. Symmetrical and asymmetrical. Public key authentication. Diffie-Hellman cryptographic protocol. Security against 'man-in-the-middle' attack.
7. SCADA/HMI design. Structure of SCADA systems. History of industrial process visualization. The position of SCADA in the control hierarchy. Free SCADA systems.
8. SCADA/HMI communication with higher and lower levels of automation devices. Communication architecture. OPC standard (classic) and OPC UA. Industrial communication standards and their position in the ISO/OSI model.
9. Cognitive approach to the design of the industrial HMI screens. Engineering-psychological aspects of human-machine interaction. Use of biological signals and eye-tracking for HMI development.
10. Database systems. Classical set operations in the relational databases and their implementation. Foreign and own keys, indexes, reference integrity, transactions. SQL Language. Commands SELECT, INSERT, and UPDATE.
11. Composition rule, fuzzy inference in the diagnosis of a technological system. Diagnostic problem formulation (symptoms, faults) with the observational fuzzy set knowledge. Composition rule application in fault diagnosis with a full (or limited) observational fuzzy set.
12. Methods of Data Mining Knowledge from databases. Classification, synthesis of rules, approximation of data. Classification of data with Support Vector Machine (SVM). Concept lattices - synthesis of rules. Approximation of data by means of Rough Sets.
13. Fuzzy controllers for the control of dynamic systems. Controller types and design steps. Modelling and simulation of the designed fuzzy controller. Control performance criteria - stability, and control accuracy.
14. Genetic algorithms. Population design, genetic operations, fitness function, GA cycle. Convergence, ending conditions. Application of GA – optimization of functions and system parameters. Weight adjustment of neural networks.
15. Fundamental concepts in Artificial Neural Networks. Artificial neuron, perceptron, multilayer perceptron network, backpropagation. ANN life cycle: training (convergence), testing, validation, and operation. Training data formation.
16. Image processing. Necessity of interpretation. Object(s) and their detection/segmentation from the image. Image acquisition. Image preprocessing without interpretation. Description of objects, extraction of features for statistical classification.
17. 3D computer vision. Single camera geometry and calibration. Two cameras, epipolar constraints informally and algebraically. The role of correspondence. Depth maps and their acquisition. 'Iterative Closest Points' algorithm. Conversion of depth maps to the surface.
18. Machine perception as feedback. Visual servo (from camera), depth map sources. Force-flexible robots, controlled mechanical impedance. Robots with tactile feedback.
19. Computer-aided software engineering, CASE, software development life cycle. Design models. Code generation. Semantic modelling, computer ontologies.
20. Object-oriented methodologies of SW analysis. OMT, lexical analysis of the requirements, UML, UML diagrams - their meaning, use, and syntax. UML use for analysis and design.