STUDY PROGRAMME

N0714A270007
Automation and Instrumentation Engineering

State-exam topics for

specialization

IT
Instrumentation Technology

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.

Modelling, control, and artificial intelligence applications

1. Static and dynamic system characteristics (linearization, step response, transfer function, system poles and zeros)
2. Frequency response (physical meaning, synthesis, asymptotic properties)
3. Stability of linear systems and control loops (definition and meaning, stability criteria – based on roots of characteristic equation, Hurwitz and Nyquist criterion)
4. Laplace and Z transforms in analysis and solution of linear systems described by differential and difference equations (definition, properties, inverse transforms)
5. Definition and properties of linear state space models (decomposition to homogeneous and relaxed solution, state transition matrix, convolution integral, system modes)
6. Analysis of nonlinear systems (singular points in the state space, limit cycle, local and global stability)
7. Numerical methods and solvers for simulation of dynamical systems (explicit and implicit methods, time step adaptation, solver parameterization in Matlab-Simulink)
8. PID controller, implementation within closed loop, control saturation and antiwindup, implementation of derivative part, manual to automatic switching, two degree of freedom controller)
9. Controller design in frequency and spectral domains – gain and phase margins, root-locus methods.
10. State space model-based control methods – controllability, observability, state feedback control, state observer
11. Application of Genetic Algorithms in optimization. Fitness function, ending conditions. Application of GA to weight adjustment of MLP neural networks.
12. Fuzzy controllers for control of dynamic systems. Controller types and design steps. Control performance criteria - stability, and control accuracy.
13. Rule-based systems in advanced control. Rule-network in control of complex systems at the interface: automatic system / human operator.
14. Application of Artificial Neural Networks for technical diagnostics. Problem formulation. Applications of convolutional neural networks.
15. Space of fuzzy values, calculation with fuzzy numbers and linguistic approximation.
16. Image processing. Necessity of interpretation. Object(s) and their detection/segmentation from the image. Image acquisition. Image preprocessing without interpretation.
17. Images and statistical recognition. Description of objects, extraction of features for statistical classification. Experimental evaluation of the classifier. Error matrix. ROC curve.
18. 3D computer vision. Single camera geometry and calibration. Two cameras, epipolar constraints informally and algebraically. The role of correspondence.
19. Depth maps and their acquisition. Stereo, structured light, shape from movement. Lidar and radar. 'Iterative Closest Points' algorithm. Conversion of depth maps to the surface.
20. Machine perception as feedback. Visual servo (from camera), depth map sources. Force-flexible robots, controlled mechanical impedance. Robots with tactile feedback.

Instrumentation engineering design

1. Methods of paraxial space image forming calculations: spherical boundary, thin and thick lens, principal planes. magnification, thin lens combinations.
2. Optical aberrations (monochromatic, colour), their correction. Stops and pupils – function, their impact on resolution, depth of field, aberration state.
3. Basic optical instruments and their characteristics: microscope, telescope (refracting, reflecting), camera. Contrast enhancing methods in microscopy.
4. Diffraction at a circular and rectangular aperture. Diffraction of light in optical instruments, its impact on resolution. Diffraction at a grating, spectrometers.
5. Interference – the conditions under which it occurs, applications: interferometers (types and applications), thin films (antireflective, dichroic mirrors, filters).
6. Polarization of light: types, Brewster angle. Birefringent materials and their applications: $\lambda/2$ a $\lambda/4$ plates, polarization filters, polarization prisms. The use in instruments (in microscopes, displays, ….).
7. Laser – generation of light, beam properties, modes. Solid-state, liquid, gas laser and ways of their pumping. Semiconductor lasers, fibre lasers. Pulse mode.
8. VIS-NIR imaging techniques: optical coherence tomography. X-ray imaging techniques: sources for imaging and diagnostic techniques, detectors; interaction of X-ray radiation with tissue (also scattering), dose, effects, Hounsfield units; computer tomography – principle, designs.
9. Sources of radiation – spectral and directional characteristics. Ideal blackbody radiation. Photometric and radiometric calculations.
10. Optical fibres – types, materials. Signal propagation through a fibre, modes. Applications: illumination, communication, sensors.
11. Finite elements methods. Element expressions (matrix methods). Kinematic boundary conditions and stress matrix modifications.
12. Design principles in precise mechanics (precision and accuracy of instruments, Abbe principle, Saint-Venant principle).
13. Methods of positioning improvement in instruments and its mechanical limits.
14. Application of piezoelectric effect in instruments design.
15. Springs, flexures and compliant mechanism in instrumentation, its production and application.
16. Thin films production (evaporation method, sputtering, CVD, lithographic techniques).
17. Production methods of micromechanical structures and its applications.
18. Vacuum, vacuum pumps, and review of vacuum elements.
19. Electron microscopes – functional principles of different electron microscopes and its limits.
20. Scanning probes microscopes – functional principles and its applications.