Topics for the State Final Examination

Academic year: **2025/2026** (exam dates in June 2026 and January/February 2027)

Type of study: **Master's degree program**

Study programme: **Mechatronics**

Thematic domain A – Power electronics, sensors and electrical drives

1. Power electronic switching devices: diodes, transistors (bipolar, MOSFET, IGBT), thyristors, and triacs. Solid State Relays. Electromagnetic compatibility, methods for reducing electromagnetic interference.

2. Thermal phenomena in power electronics. Thermal design (cooling dimensioning) of power semiconductor devices. Protection circuits for semiconductor switches: avalanche diodes, varistors, semiconductor fuses, surge arresters. Passive components in power electronics: electrolytic capacitors, pulse capacitors, ferrite inductors and transformers.

3. Power converters (AC/DC, DC/DC, DC/AC) and their applications in electrical drives and lighting systems.

4. Piezoelectric sensors and resonators: material properties, operating modes, equivalent circuits, and applications in measurement, MEMS technologies, and methods for measuring mechanical quantities (strain, displacement).

5. Strain gauge measurements, connection of strain gauges into the quarter-bridge, half-bridge and full bridge. Optical methods in deformation measurements, high-speed imaging. Rotary motion (angular speed and position) sensors: encoders (absolute & incremental), resolvers.

6. Brushed DC motors and brushless DC motors: working principles, speed control, braking, mathematical model of a DC motor, control of position, velocity and torque of a DC drive, control structures.

7. Induction motor: principle, construction, voltage equations and equivalent circuit, energy balance and motor torque, frequency speed control, scalar and vector control strategies, direct torque control, control structures for induction motor-driven servomechanisms.

8. Synchronous motor: principle, construction: synchronous motor with permanent magnets in rotor (PMSM): construction, properties, mathematical model, control of position, velocity and torque.

9. Basic principles of frequency converters: HW arrangement, recuperation of electric energy, indirect frequency converter with current- and voltage-source DC-link, direct converters, matrix converter, three-phase pulse-width modulation.

10. PLC open motion control, single axis control, multi axis control, synchronized motions, motion safety, gearboxes.

Thematic domain B – Automatic control, real time systems and signal processing

11. Input output models of continuous dynamic systems: differential equations, transfer functions, frequency domain transfer functions, Nyquist and Bode plots, step and impulse responses, linearization of nonlinear systems, principle of superposition.

12. Discretization of continuous time systems, Z transform, discrete-time models of linear systems.

13. Stability of linear continuous-time and discrete-time systems, derivation of stability regions, reasons why stability regions of continuous and discrete systems are different, stability criteria {algebraic and frequency domain).

14. Design of digital controllers, discrete-time equivalents of PID controllers, digital controllers with finite settling time.

15. State-space models of linear systems, stability, observability, controllability, interpretation and impact of eigenvalues on system dynamics. State feedback controllers, achieving zero steady state error with state feedback controllers.

16. The concept of the real-time systems, difference real-time vs non real-time systems, real-time scheduling algorithms and schedulability testing.

17. Main components of Free RTOS: threads, semaphores, mutexes, queues, software timers etc. Main uses of semaphores and mutexes, priority inversion problem, protocols for priority inversion control.

18. Correlation of deterministic signals, Discrete-Time Fourier Transform (DTFT), difference equations and their solution by recursive substitution and using the DTFT, signal-to-noise ratio, aliasing.

19. Fast convolution of long data sequences, overlap-add and overlap-save methods, Fast Fourier Transform, spectral analysis.

20. Digital filtering, sampling, design and implementation of FIR and IIR filters.

Thematic domains C – Image processing, artificial intelligence and robotics

21. Image acquisition, representation and pre-processing: transformations of pixel brightness, camera calibration, filter operations, convolution filters, morphological filters.

22. Image feature extraction: colour, texture and shape descriptors.

23. Image classification: nearest neighbour (NN), k-nearest neighbour (KNN), statistical classifiers, template matching, decision trees, application of convolutional neural networks and support vector machines to image classification.

24. Machine learning: supervised and un-supervised learning methods, support-vector-machines (SVM), principal component analysis (PCA), hidden Markov models (HMM), clustering (K-Means).

25. Artificial neural networks, similarities and differences in the architecture of MLP (Multi-Layer Perceptron) and SOM (Self-Organizing Map), optimization objectives of the MLP and SOM methods, key steps in data preparation, characteristics of the learning curve.

26. ROS and software architecture of robotic systems: node, topic, message, service, action, launch files, parameters, packages, working with bag files, role of simulations.

27. Localization, mapping, and SLAM using LiDAR, local vs. global localization, types of localization problems, particle filter, map-based localization, definition of the SLAM problem.

28. Motion planning, navigation, and configuration space, definition of configuration space, Minkowski sum for obstacle expansion, importance of C-space for trajectory planning, Path planning algorithms (graph-based algorithms, heuristic algorithms), local planning and global planning, Navigation procedure based on Nav2 navigation stack.