High-Tech Systems Design

High-Tech Systems Design	
Offered by	Department of Mechanical Engineering
Language	English
Primarily interesting for	All students, but most relevant for students with background in ME, EE, AT, IE, AP, AM&CSE
Prerequisites	Required courses: Dynamics and control Recommended courses:
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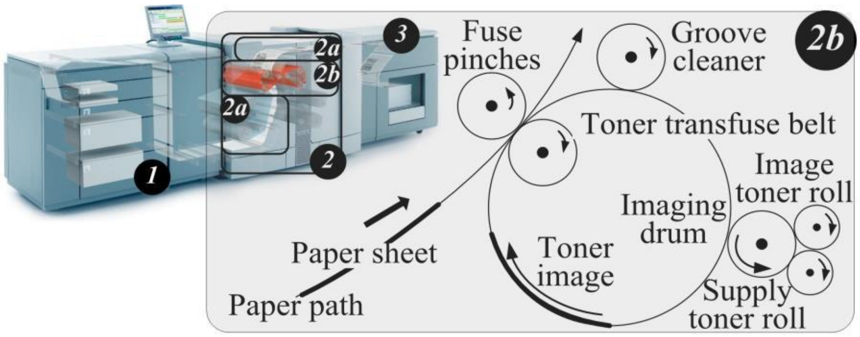
Last year of education/exam given	2026-2027

Content and composition

In this elective package students are introduced to a structured design method for multidisciplinary high-tech systems (HTSs), in which the focus is on an integrated design approach. A number of design steps will be addressed in detail in specific examples.



HTSs are complex systems built as an answer to societal problems in the areas of mobility, aging, ecology, energy, and so on. Innovation in the development of high-tech systems is of crucial importance to the preservation of our prosperity and wellbeing. Applications of HTSs such as robotics, motion controllers, guided transport systems and embedded systems, can be found in semiconductor and nanotech systems, micro- and nano-assembly systems, logistic systems, production automation and systems for handling, packaging, printing and processing goods. The design of such systems requires a multidisciplinary approach combining the design of high-performance mechatronic systems including motion control and supervisory control. Precision-controlled motion systems and robotic systems are prominent examples of such.

Course code	Course name	Level classification
4TC00 (2023-2024 and 2024-2025) Q1 4CB40 (2025-2026 and 2026-2027) Q3	Model-based Systems Engineering Control of Manufacturing Systems	Deepening
4CC10 (2023-2024 and 2024-2025) Q3 (2025-2026 and 2026-2027) Q4	Mechatronic Design	Advanced
4DC00 (2023-2024 and 2024-2025) Q4 (2025-2026 and 2026-2027) Q3	Dynamics and Control of Robotic Systems	Advanced

High-Tech Systems Design

Course description

Model-based Systems Engineering (4TC00)
Students are introduced to the model-based systems engineering (MBSE) framework for the design of supervisory controllers as part of a high-tech system. In this framework, combined continuous-time and discrete-event models are made of the uncontrolled system (plant) and of the supervisory controller. After analysis of the behavior of the model of the controlled system by means of interactive simulation and visualization, the real-time controller is generated from the model of the controller. This real-time controller is first tested on a Digital Twin and finally on the actual system. In the course, the concepts that are needed are introduced and both the practical application and the theoretical foundations are discussed.

The subjects covered in this course are:

- Introduction High-tech Systems Design:
  - Characteristics of high-tech systems
  - Architecture of high-tech systems
  - Design models for high-tech systems
- Introduction Model-based System Engineering (MBSE):
  - Introduction and elaboration of the MBSE framework
  - Designing and interfacing plant models and controllers
  - Validation by interactive simulation and visualization
  - Code generation and real-time PLC control
- Definition and analysis of continuous-time, discrete-event and hybrid models:
  - Hybrid automata
  - Discrete-event synchronization and communication
  - Hybrid simulation
  - Mathematical statement of the involved concepts
- Industrial applications of supervisory control:
  - MBSE of airport baggage handling systems
  - Patient Support System of an MRI scanner
- MBSE of a supervisory controller for a manufacturing line
  - Design and simulation-based validation of plant model and supervisory controller
  - Code generation for real-time execution on Festo industrial components
  - Testing of the generated controller on a supplied 3D Digital Twin
  - Actual testing of the controller in a lab

Mechatronic Design (4CC10)
Prerequisite knowledge: dynamics and control
This is an introductory course into the multi-disciplinary development of mechatronic systems. Students will acquire broad technical knowledge beyond the limits of their own discipline: Conceptual mechanical and electrical design based on functional and control requirements.

The subjects covered in the course are:

- Introduction High Tech Systems
- Systems Engineering, CAFCR, V model
- Basic modeling of motion systems
- Applied machine dynamics
- Electromechanics/ motor selection
- Introduction to design principles (degrees of freedom, kinematic constraints, flexures)
- Humanware in mechatronic development
- Fundamentals of (digital) motion control
- Simulation
- Sensors & metrology
- Case Study

High-Tech Systems Design

Dynamics and Control of Robotic Systems (4DC00)
This course provides an introduction to the modeling, analysis, and control of robotic systems. Robotic systems have become pervasive in many parts of our society; examples are manufacturing robots in factories, health care (surgical) robots, robots used for surveillance and security, soccer playing robots, mobile robots on Mars, and many more. The appropriate description of the kinematics and dynamics is a key feature when studying this type of systems. The difference between the joint space (related to ``how the robot is built'') and the task space (related to ``what the robot is supposed to do'') unavoidably leads to highly nonlinear kinematic relationships. These nonlinearities make the control of the robot towards a set-point (or tracking a desired trajectory in space) a true challenge. Numerical simulations and practical examples will be used to illustrate these concepts.

The subjects covered by the course comprise:

- Introduction to robotics and its applications
- Kinematics of a robotic system and the Denavit-Hartenberg convention
- Rotation matrices, Euler and Cardan Angles
- Joint and task spaces, coordinate transformations
- Dynamics of a robotic system, in particular, of a serial manipulator
- State Space Modeling for control
- Control of rigid robots, computed torque method
- Introduction to mobile wheeled robotics
- Simulation of kinematic and dynamic robotic systems
- Derivation of the kinematics and dynamics of a serial manipulator
- using MATLAB Symbolic Math Toolbox
- Case studies on mobile robots and serial manipulators