UNIVERSITY OF SOUTHERN DENMARK

Chapter 9
The Programme Specific Part of the Curriculum for

CIVILINGENIØR, CAND.POLYT. I MEKATRONIK
Master of Science in Engineering – Mechatronics

Curriculum 2012, Version 1.0

Applicable to students admitted September 2012 onwards

The curriculum is divided into general provisions (Chapters 1-8), a programme specific part (Chapter 9) and the module descriptions for the subjects studied for each programme. Students should familiarise themselves with all three parts in order to acquire a full overview of the rules that apply throughout the study programme.

§1 Job profiles

An engineer with a Master of Engineering degree in Mechatronics from The University of Southern Denmark has a broad knowledge of mechanical-, electronic- and software engineering. Furthermore, the student has the possibility of specialising in one of the profiles: Nanotechnology, Embedded Control Systems, Dynamic Mechatronic Systems or Thermal Energy Technology. The study programme focuses on product development. The mechatronics engineer will typically find employment in companies which develop and sell mechatronic products. With broad general knowledge and special key competences the mechatronic engineer can occupy many different positions. Typical job profiles include:

- Research and Development
- University positions – PhD programmes
- Project manager
- Consultant
- Project sales
- Teaching

The mechatronic engineer will typically start the career as a research and development engineer and will, in the course of a few years, have the opportunity of combining the technical work with managerial work.

The mechatronic engineer often participates in development processes across organisations and is involved in collaboration with external companies, nationally and internationally. Alternatively, the mechatronic engineer can become a specialist and do research within specific technologies or start up his/her own company.

§2 Competencies Provided by the Study Programme

The aim of the Master of Science in Engineering study programme in Mechatronics is to educate a development engineer with competencies in mechanics, electronics and software including the interplay between the technologies. The study programmes qualifies the graduate engineer to carry out, participate in or lead the development of mechatronic products. Furthermore the graduate will be qualified to do research in the context of a PhD programme.

A Master of Engineering in Mechatronics from the University of Southern Denmark is characterised by mastering the following competencies:

- The ability to design and calculate mechanical designs
- The ability to design and calculate electronic circuits
- The ability to develop software for intelligent products
- The ability to participate in a company's development department independently and together with others
- The ability to apply technological knowledge and theories for the development of new products
- Specialised knowledge within either of the profiles: Nanotechnology, Embedded Systems, Dynamic Mechatronic Systems or Thermal Energy Technology
- The ability to carry out development projects independently and in teams
- The potential to become a project manager of product development assignments
- Knowledge of the highest level of research in the chosen profile
- Can understand and reflect on the knowledge at a scientific level
- Can identify scientific problems of research in the chosen profile

The MSc engineering programme also gives the graduate skills in analysing and modelling systems, seeking out new knowledge, and understanding and utilising research results within the graduate's own field of specialisation in order to develop new concepts and product types.

§3 Subject Columns and Profiles

The Mechatronic Programme is divided into two main subject columns, - one covered by the theme: “Advanced Mechatronics and Scientific Methods”, and one covered by an elective profile. The mechatronic engineer acquires the competencies by working with subjects from both columns.

The themes are:

- **Advanced Mechatronics and Scientific Methods**: This theme covers core competences for all mechatronic students. The courses are mandatory and constituent.

- **Profile in Nanotechnology**: This theme covers courses and project work that specializes into the research level of nanotechnology in a mechatronic context.

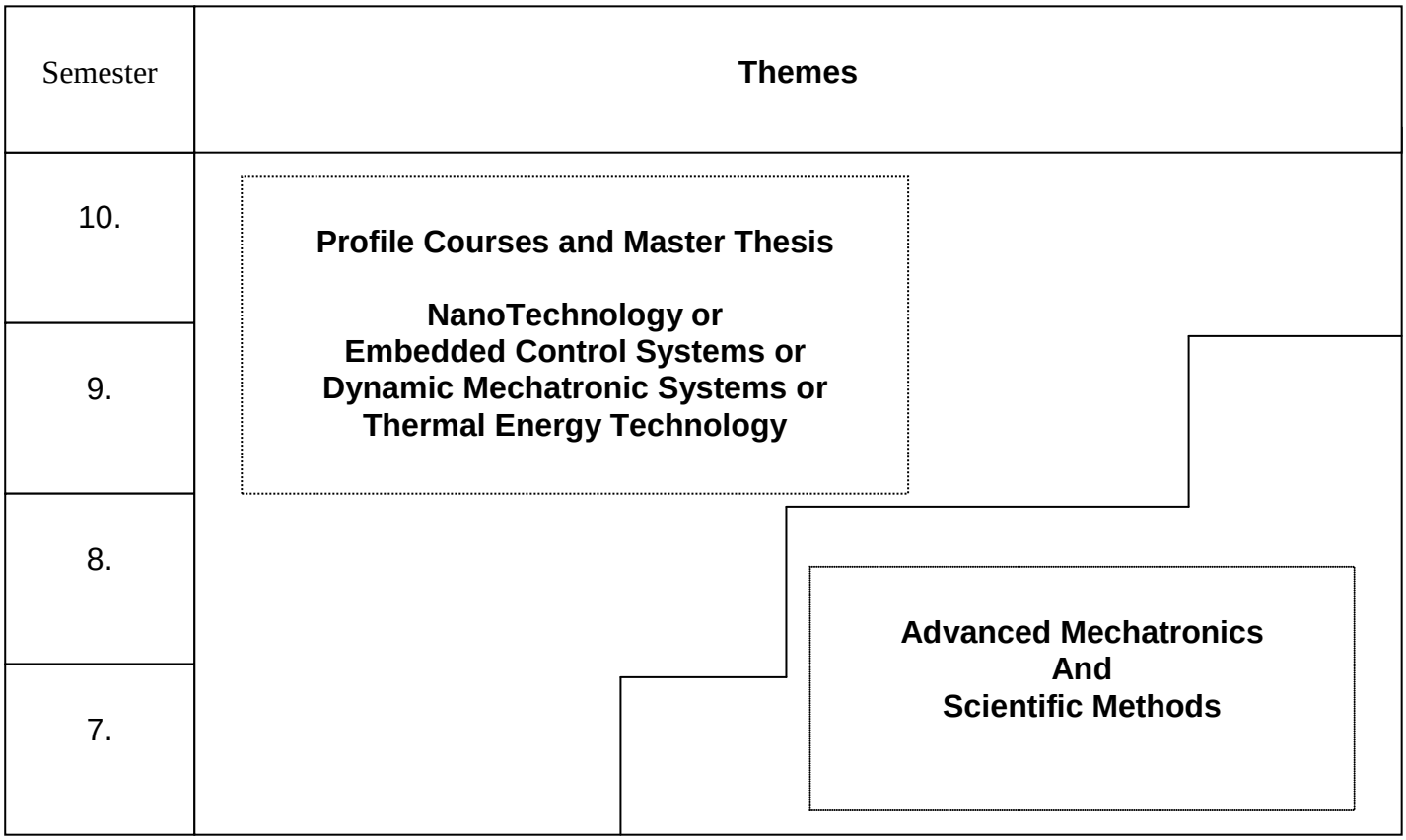
- **Profile in Embedded Control Systems**: This theme covers courses and project work that specializes into the research level of embedding control systems into mechatronic products.

- **Profile in Dynamic Mechatronic Systems**: This theme covers courses and project work that specializes into the research level of analyzing, modeling and developing dynamic mechatronic systems.

- **Profile in Thermal Energy Technology**: This theme covers courses and project work that specializes into the research level of analyzing, modeling and developing systems related to thermal energy.

The students will choose one of the four profiles. The profile courses are constituent and the profile includes the master Thesis and the possibility of 10 ECTS elective course

§4 Themes and Profiles



§5 Structure and modules

<table>
<tr><td>Semester</td><td colspan="20">Master of Science in Engineering – Mechatronics
Profile in Nanotechnology</td></tr>
<tr><td>10.</td><td colspan="20">THS-U2 (30 ECTS)
Master Thesis</td></tr>
<tr><td>9.</td><td colspan="5">MCNPRO 2
Nanoproject</td><td colspan="6">MCMICRO 2
Micro- and Nano fabrication</td><td colspan="5">THS-U1 (40 ECTS) / Electives
Master Thesis / Electives</td><td colspan="4" rowspan="2">NAMDB 2
Mechatronics Design and Build</td></tr>
<tr><td>8.</td><td colspan="5">MCNPRO 1
Nanoproject</td><td colspan="3">MCINFO
Interface Optics</td><td colspan="3">NCNPHYS
Nanophysics</td><td colspan="3">MCSMS
Scientific Methods</td><td colspan="4">MCESD
Embedded Software Design</td></tr>
<tr><td>7.</td><td colspan="8">MCIECS or MCMICRO 1 and MCSURF
Introduction to Embedded Control Systems or
Introductory courses MICRO 1 and SURF</td><td colspan="4">NAFEA
Finite Element Analysis</td><td colspan="3">MCNUA
Numeric Analysis</td><td colspan="8">MCCOS
Control Systems</td></tr>
<tr><td>ECTS POINT</td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1</td></tr>
</table>

Semester	Master of Science in Engineering – Mechatronics **Profile in Embedded Control Systems**																												
10.	**THS-U2 (30 ECTS)** Master Thesis																												
9.	**MCEPRO 2** Project in Emb. Real Time Control Systems					**MCRTS** Real Time Systems					**MCDIS** Distributed Embedded Systems					**THS-U1 (40 ECTS) / Electives** Master Thesis / Electives Elective Course: Time Control Systems										**NAMDB 2** Mechatronics Design and Build		
8.	**MCEPRO 1** Project in Emb. Systems Design and Analysis					**MCCOD** HW/SW Co-Design of Embedded Systems					**MCVVA** Emb. Systems Verification and Validation					**MCSMS** Scientific Methods					**MCESD** Embedded Software Design							**NAMDB 1** Mechatronics Design and Build
7.	**MCIECS** Introduction to Embedded Control Systems										**NAFEA** Finite Element Analysis					**MCNUA** Numeric Analysis					**MCCOS** Control Systems								
ECTS POINT	1																												1

<table>
<tr><td>Semester</td><td colspan="25">Master of Science in Engineering – Mechatronics
Profile in Dynamic Mechatronic Systems</td></tr>
<tr><td>10.</td><td colspan="25">THS-U2 (30 ECTS)
Master Thesis</td></tr>
<tr><td>9.</td><td colspan="5">MCNCON
Nonlinear Control</td><td colspan="8">NAMMM 2
Mathematical Modelling</td><td colspan="7">THS-U1 (40 ECTS) / Electives
Master Thesis / Electives</td><td colspan="5">NAMDB 2
Mechatronics Design and Build</td></tr>
<tr><td>8.</td><td colspan="9">MCDPRO
Verifying Mathematical Models</td><td colspan="5">MCMMM 1
Mathematical Modeling</td><td colspan="5">MCSMS
Scientific Methods</td><td colspan="5">MCESD
Embedded Software Design</td><td colspan="5">NAMDB 1
Mechatronics Design and Build</td></tr>
<tr><td>7.</td><td colspan="9">MCIECS
Introduction to Embedded Control Systems</td><td colspan="5">NAFEA
Finite Element Analysis</td><td colspan="5">MCNUA
Numeric Analysis</td><td colspan="10">MCCOS
Control Systems</td></tr>
<tr><td>ECTS POINT</td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1</td></tr>
</table>

Semester	Master of Science in Engineering – Mechatronics **Profile in Thermal Energy Technology**																													
10.	**THS-U2 (30 ECTS)** Master Thesis																													
9.	**MCNCON** Nonlinear Control					**MCMMHC** Mathematical Modelling of Heat Conduction					**MCTMS** Thermal Modeling Seminar					**THS-U1 (40 ECTS) / Electives** Master Thesis / Electives										**NAMDB 2** Mechatronics Design and Build			
8.	**MCTPRO** Thermal Project										**MCMMM 1** Mathematical Modeling					**MCSMS** Scientific Methods					**MCESD** Embedded Software Design								**NAMDB 1** Mechatronics Design and Build
7.	**MCPDA** Process Design and analysis					**MCTFD** Thermal and Fluid Dynamics					**NAFEA** Finite Element Analysis					**MCNUA** Numeric Analysis					**MCCOS** Control Systems									
ECTS POINT	1																													1

§6 Description of the theme:

Advanced Mechatronics and Scientific Methods.

Introduction (Argumentation of values):

Mechatronics is by nature interdisciplinary. The core competence in mechatronics is to be able to combine technologies and methods from at least three different areas: Electronics, Software and Mechanics, with the emphasis on developing modern intelligent products. Therefore it is mandatory, that mechatronic students get generic theoretic knowledge as well as practical skills so they can understand the latest research results and bring them into the context of developing mechatronic products.

Furthermore mechatronic products can be developed on different scales, from small (nano) to big. Developing farming machines, cameras, cell phones or intelligent sensors can all be called developing mechatronic products.

The "Advanced Mechatronics and Scientific Methods" theme is the generic and basic part of the master programme. It is necessary, that all students achieve knowledge of the core disciplines and their interaction, to be part of the "mechatronic world". By combining this with one of the four profiles: Nanotechnology, Embedded Control Systems, Dynamic Mechatronic Systems or Thermal Energy Technology, the student will become a specialist with knowledge of the highest international level in the chosen profile in the context of a general mechatronic engineering education.

Competency goals:

Having passed the courses in the Advanced Mechatronics and Scientific Methods theme, the student has the following competencies:

- Understands the mathematical basis of the finite element method
- Can solve a wide range of physical problems with a commercial finite element program.
- Can formulate engineering problems as mathematical models.
- Can analyze and solve engineering problems numerically.
- Has knowledge on theoretical and practical elements of control systems based on state-space theory.
- Can analyze, design, simulate and implement real-time control systems.
- Has advanced knowledge of embedded software design methods and tools.
- Can develop software that is inherently correct by design.
- Understands the mechatronic development process "in depth".
- Can develop mechatronic systems with the emphasis on using state-of-the-art smart materials for sensing, actuating and control.

Context:

The theme consists of the modules:

- Finite Element Analysis (NAFEA, 5 ECTS), Numeric Analysis (MCNUA, 5 ECTS) and Control Systems (MCCOS, 10 ECTS) on the 7th semester.

- Scientific Methods (MCSMS, 5 ECTS), Embedded software Design (MCESD, 5 ECTS) and Mechatronics Design and Build (NAMDB 1, 5 ECTS) on the 8th semester.

- Mechatronics Design and Build continued (NAMDB 2, 5 ECTS) on the 9th semester.

All courses are mandatory to mechatronic students.

§7 Description of the profile:

Nanotechnology.

Argumentation of values.

Our modern life gets faster and technological based products are becoming cheaper. Therefore consumers demand smaller, faster and more flexible products which also has its consequences in the interdisciplinary area of Mechatronics. The field of Mechatronics combines a number of established areas of science and engineering, such as mechanical engineering, electronics, control engineering, as well as micro- and nanotechnology.

With the ongoing trend in engineering and modern information technology of ongoing miniaturization nanotechnology gains more and more impact also in the area of mechatronics. Electromechanical systems are reaching dimensions on the nanoscale and the accompanying electronic devices cannot neglect anymore principles of quantum mechanics. The Master programme enables the students to cope with these modern developments and therefore sets a solid basis to increase the chances for employment.

Competence goals

The NANO profile consists of lecture courses and semester projects delivered in the 8th and 9th semesters, respectively.

After having successfully finished the program, the master student with specialisation ‘nanotechnology’ will have:

- a general knowledge about basics and modern trends in nanotechnology
- knowledge about the principle of micro- and nanofabrication methods
- the ability to independently work in a cleanroom
- the ability to identify appropriate semiconductor processing methods for micro- and nanoscaled devices
- knowledge of how to use photonics methods in nanotechnology
- a thorough understanding of the principles of micro- and nanoelectromechanical systems and the effects of low-dimensionality

The following section presents the structure and contents of the M.Sc. programme in Mechatronics with specialisation Nanotechnology in more detail. The latter has been developed taking into account the following guidelines:

- Course contents reflect the state of the art and modern trends in the area of nanotechnology, taking also into account the needs of industry using nano- and microtechnology
- Semester projects integrate knowledge given in the specialized courses delivered in the corresponding semesters, and provide hands-on and teamwork experience to students

- Vertical integration of courses is an important assumption, providing for gradual progression - from fundamental knowledge given in programme courses to specialized and dedicated solutions given in profile courses

- B.Sc. courses provide basic knowledge and practical engineering skills, whereas master courses give advanced knowledge emphasizing design skills, as well as the integration of education and research.

It is assumed that students applying for the NANO programme have basic knowledge in nanotechnology at the level corresponding to the B.Sc. programme in Mechatronics Engineering of MCI with specialisation nanotechnology and similar programmes at other places.

Context

The Nanotechnology programme is structured into...

Table 1

Semester	Courses / Projects	ECTS	Type
Semester 8	Interface Optics Nanophysics Nano project	5 5 5	Profile Course Profile Course Profile Project
Semester 9	Micro- and Nanofabrication Nano project Thesis or electives*	10 5 10	Profile Course Profile Project Profile Course
Semester 10	Thesis	30	Final Project

** In the 9th semester, it is possible to choose between elective courses or commence on a 40 ECTS thesis to be completed in the 10th semester.

Fig. 1. M.Sc. Programme Framework

The contents of the NANO courses and projects are briefly outlined below:

The courses delivered in the 8th semester are aimed at giving advanced knowledge in the area of Nanophysics and Interface Optics, focusing on the physics related to nanostructures and modern characterisation methods. These include courses in Nanophysics and Interface Optics.

The courses delivered in the 9th semester build on this knowledge and the courses in the Bachelor education – in particular the cleanroom microfabrication course - and develop it further in terms of advanced micro- and nanosystems development and processing. These include a course in Micro- and Nanofabrication and a research project.

It is also possible to choose elective courses or carry out preliminary research and development, in preparation for the Final project executed in Semester 10.

Course tracks

Students coming from our own bachelor profile nanotechnology will attend the Introduction to Embedded systems course.

Students having another profile or coming with a bachelor from another university should take the introductory courses MCMICRO1 and MCSURF upgraded to master level by including additional teaching material.

§8 Description of the profile:

Embedded Control Systems

Introduction (Argumentation of values):

Mechatronics is an interdisciplinary area combining a number of established areas of science and engineering, such as mechanical engineering, electronics, control engineering, as well as hardware and software engineering. A mechatronic system integrates a mechanical plant with a control system consisting of various sensors, actuators and one or more embedded microcontrollers (sometimes integrated with other kinds of programmable devices like signal processors, field-programmable gate arrays, dedicated systems-on-chip, etc.), implementing the required control functionality in software.

The widespread use of microcontrollers has been a major development in recent years, with billions of microcontrollers introduced every year in various kinds of control and monitoring applications, including a broad variety of mechatronic systems. Nowadays, there is no single piece of equipment without an embedded control system, and this gives a new, quantitative dimension to the problem of control system design, in addition to the great diversity and ever growing complexity of embedded applications.

In this context, embedded systems hardware/software development plays a major role. Unlike hardware development, software development is presently dominated by conventional design methods and manual coding techniques. However, these are not able to cope with continuously growing demands for high quality of service, reduced development and operational costs, reduced time to market, as well as ever growing demands for software safety and dependability. In particular, software safety is severely affected by design errors that are typical for informal design methods, as well as implementation errors that are introduced during the process of manual coding.

This situation has stimulated research into new software design methods based on formal design models specifying system structure and behaviour that can be verified and validated before the generation of the program code. Furthermore, it is assumed that software development will be supported by computer-aided development environments and repositories of prefabricated components. It is expected that the adoption of such methods will ultimately lead to industrial software design technology that will make it possible to develop embedded control systems that are correct by design, while considerably reducing software development costs and time to market. Similar developments have already taken place in the area of hardware design, where computer-aided design and formal verification of large-scale integrated circuits have been well established over the years.

The outlined trends in the evolution of mechatronic systems and the ever growing importance of embedded control systems have motivated the development of the Embedded Control Systems (ECS) profile of the B.Sc. and M.Sc. programmes in Mechatronics Engineering offered at the Mads Clausen Institute for Product Innovation, University of Southern Denmark. The goal of the ECS profile is to educate engineers with competences needed to design and build embedded control systems for a broad range of mechatronic applications (e.g. process control, motion control, robotics, industrial automation, etc.) taking into account the latest trends and developments in relevant areas, such as microcontroller technology, sensors and actuators, embedded software design, real-time systems and industrial computer networks.

Competency goals:

The ECS profile consists of lecture courses and semester projects delivered in the 7th, 8th and 9th semesters, respectively. The seventh semester programme consists of a single 10-ECTS Transfer Block Project. This is an introductory project, whose purpose is to provide students with basic knowledge and practical skills needed to continue their studies in the following semesters. The scope and contents of the project are determined depending on the background and previous experience of the students. The

theme of the 8th semester is formulated as “Embedded Systems Design and Analysis”. This block consists of several courses and a semester project whose goal is to develop competences in advanced software design methods featuring model-driven and component-based design/analysis of embedded software, as well as hardware/software co-design of embedded systems using programmable digital circuits. The theme of the 9th semester is formulated as “Distributed Real-Time Control Systems”. This block consists of lecture courses and a semester project whose goal is to provide advanced knowledge and competences needed to develop complex real-time control systems operating in distributed environments provided by modern industrial computer networks.

The following section presents the structure and contents of the M.Sc. programme in Embedded Control Systems in more detail. The latter has been developed taking into account the following guidelines:

- Course contents must reflect the state of the art and modern trends in the area of embedded systems, taking also into account the engineering profile of the local industry
- Semester projects integrate knowledge given in the specialized courses delivered in the corresponding semesters, and provide hands-on and teamwork experience to students
- The curriculum has to be developed in an evolutionary manner, taking into consideration the accumulated experience and best practices established over the years in the MCI
- Vertical integration of courses is an important assumption, providing for gradual progression - from fundamental knowledge given in programme courses to specialized and dedicated solutions given in profile courses
- B.Sc. courses provide basic knowledge and practical engineering skills, whereas master courses should give advanced knowledge emphasizing design skills, as well as the integration of education and research.

It is assumed that students applying for the ECS programme have basic knowledge in electronics, computer architecture and programming, microcontrollers (hardware and software) and control engineering at the level corresponding to the B.Sc. programme in Mechatronics Engineering of MCI and similar programmes of SDU and other universities in Denmark and abroad.

Upon graduation, the students will have competences in a number of relevant areas. In particular, they will be able to:

- understand the principles of operation of embedded control systems, i.e. computer-plant interaction and real-time computer operation in sequential, continuous and hybrid control systems;
- develop embedded software that is inherently correct by design, by applying advanced model-driven and component-based design methods and tools, as well as modern industrial software standards;
- develop complex embedded applications using advanced hardware/software co-design methods and tools;
- analyze the behaviour of embedded systems by means of modern verification and validation methods and tools;
- understand the architecture and principles of operation of hard real-time systems and apply relevant design and analysis methods;

- develop real-time emebedded control systems using state of the art real-time operating systems (kernels), as well as design and analysis tools;

- understand the architecture and principles of operation of distributed embedded systems, i.e. distributed real-time systems, industrial computer networks and protocols and related industrial standards;

- develop distributed real-time computer control systems for complex embedded applications.

Having received advanced knowledge and training in the above areas (including recent trends and latest results), ECS programme graduates will be able to take part in the research activities of industrial companies manufacturing mechatronic products and systems, as well as companies and research institutions specializing in embedded control systems and embedded hardware/software development.

Programme structure and contents (context)

The Embedded Control Systems programme is structured into three groups of courses and projects that will be delivered in semesters 7, 8 and 9, followed by final project (see Table). These courses are profile courses that are delivered together with other programme courses such as Numerical Analysis (MCNUA), Finite Element Analysis (NAFEA), Control Systems (MCCOS), Mechatronic Design and Build (NAMDB), etc., which are delivered to all profiles of the MCI Mechatronics programme, etc. In particular, the MCCOS course provides the necessary control-theoretical background to ECS students, whereas the profile courses emphasize computer technology used to engineer modern computer control systems for embedded applications. One of these, i.e. Embedded Software Design (MCESD) will be delivered to all Mechatronics students as a programme course.

Semester	Courses / Projects	ECTS	Type
Semester 7 Transfer Block Project	Introduction to Embedded Control Systems	10	Profile Project
Semester 8 Embedded Systems Design and Analysis	Embedded Software Design Hardware/Software Co-Design of Embedded Systems Embedded Systems Verification and Validation Project in Embedded Systems Design and Analysis	5 5 5 5	Programme Course Profile Course Profile Course Profile Project
Semester 9 Distributed Real-Time Control Systems	Real-Time Systems Distributed Embedded Systems Project in Embedded Real-Time Control Systems Thesis / Specialized Profile Courses*	5 5 5 10	Profile Course Profile Course Profile Project Profile Courses
Semester 10	Thesis	30	Profile Project

* In the 9th semester, it is possible to choose between elective courses or commence on a 40 ECTS thesis to be completed in the 10th semester.

The contents of the ECS courses and projects are briefly outlined below:

The Transfer Block project “Introduction to Embedded Control Systems” is executed in the 7th semester, in preparation for the main courses delivered in the following semesters. The scope and subject of the project will be chosen depending on the background of the students, emphasizing specific areas such as embedded control systems architecture and principles of operation, embedded systems programming and FPGA-based design, as necessary. The programme course in Control Systems (10 ECTS) is also delivered in this semester, giving the students the necessary control-theoretical background needed to develop modern computer control systems.

The courses delivered in the 8th semester are aimed at giving advanced knowledge in the area of Embedded Systems Design and Analysis, focusing on modern model-driven and component-based design and analysis methods. These include courses in Embedded Software Design, Hardware/Software Co-Design of Embedded Systems and Embedded Systems Verification and Validation, which are delivered together with the first part of the Mechatronics Design and Build course. A semester project in

Embedded Systems Design and Analysis will be executed, integrating the knowledge given in the semester courses, aimed at developing control systems for mechatronic devices, such as electrical motor, inverted pendulum, lift, etc.

The courses delivered in the 9th semester build on this knowledge and develop it further in the context of Distributed Real-Time Control Systems featuring multiple concurrently executing tasks with hard deadlines, running in distributed operational environments provided by various types of computer networks. This block consists of two courses - Real-Time Systems and Distributed Embedded Systems, which are delivered together with the second part of the Mechatronics Design and Build course. A semester project in Embedded Real-Time Control Systems will be executed, integrating the knowledge given in the semester courses, aimed at developing distributed control systems for complex applications, such as quad-rotor helicopter, production cell, turntable cell, process control experiment, etc.

It is also possible to choose elective courses or carry out preliminary research and development, in preparation for the Final project executed in Semester 10.

Elective and specialized courses

Elective courses are complementary to the main courses presented above. These could be dedicated to important areas of research and development, e.g. digital signal processors, intelligent sensors and actuators, hardware/software co-design of embedded systems, etc., whenever these are not covered (sufficiently) by the main courses.

It is also possible to have specialized courses dedicated to specific products and technologies, e.g. new hardware/software technologies, software development environments, operating systems and communication protocols, etc., that may be related to the final project. In this case, teaching will be product-oriented, as against the problem-oriented approach used in other courses, thus achieving a suitable balance between higher university education (emphasizing methodology), and technical education (emphasizing technology).

The list of elective courses will be updated every year, so as to closely follow the latest developments in the field of embedded control systems. Specialized courses may be delivered by industrial experts.

Course tracks

ECS courses will be attended by students who have graduated from the MCI with a BSc or BEng degree in Mechatronics, or an equivalent degree obtained from another university in Denmark and abroad. Therefore, they are expected to have different backgrounds, which may or may not require the inclusion of introductory projects (or the same kind of project) in the corresponding study programmes (tracks). Presently, three such tracks have been identified taking into account the background of expected applicants:

- Students coming from the BSc Programme of the MCI
  - Semester 7: Semester project MCIECS for internal students
  - Semester 8: Courses in Embedded Control Systems; Programme courses (NAMDB1, MCESD, etc.)
  - Semester 9: Courses in Embedded Control Systems; Programme course (NAMDB2); Thesis preparation and/or specialized courses
  - Semester 10: MSc Thesis
- Students coming from BSc Programmes of other universities
  - Semester 7: Semester project MCIECS for external students

- Semester 8: Courses in Embedded Control Systems; Programme courses (NAMDB1, MCESD, etc.)
- Semester 9: Courses in Embedded Control Systems; Programme course (NAMBD2); Thesis preparation and/or specialized courses
- Semester 10: MSc Thesis

• Students coming from the BEng Programme of the MCI

- Semester 8: Courses in Embedded Control Systems; Programme courses (NAMDB1, MCESD, etc.)
- Semester 9: Courses in Embedded Control Systems; Programme course (NAMBD2)
- Semester 10: Elective and/or specialized courses; Thesis preparation
- Semester 11: MSc Thesis

§9 Description of the profile:

Dynamic Mechatronic Systems

Introduction

The goals and competencies behind this profile are to provide students with a general, broad introduction to advanced themes related to applied mathematics, control, modeling of physical systems using both analytical and computational techniques. With the increasing demand of improving product development in industry, mathematical-modeling support is becoming a major tool to avoid standard trial-and-error product innovation so as to minimize the total product development time. As the Dynamic Systems (DS) profile is a profile providing students with strong applied mathematical skills in relation to mechatronics and dynamical systems, candidates will be qualified to undertake advanced analytical mathematical and physics problems in the mechatronics industry. Naturally, students taking this profile would be candidates subsequently for mathematical modeling phd projects related to mechatronic components and systems (control) linking well to our present research activities. All courses on this profile are research-based in the sense that course contents reflect the ongoing research activities in the mechatronics areas at MCI.

Competence goals

The DS profile consists of lecture courses and semester projects delivered in the 7th, 8th and 9th semesters. The seventh semester programme consists of a single 10-ECTS MCIECS. This is an introductory module whose purpose is to provide students with basic knowledge and practical skills needed to continue their studies in the following semesters. The scope and contents of the course are hands-on microcontrollers and digital electronics. The theme of the 8th semester is formulated as “Use of mathematical modelling tools in mechatronic systems with control applications”. This block consists of several courses (including MCMMM1) and a semester project (MCDPRO) where the goal is to develop the student’s competences in advanced mathematical tools in engineering. The theme of the 9th semester is formulated as “Advanced analytical methods and nonlinear control”. This block consists of lecture courses NAMMM2 and MCNCON.

In short, the DS profile provides student’s with competences and effective tools for solving problems of mathematical nature in product development and research. The students, in particular, will learn when to use analytical techniques and when computational techniques are required. This is very important in the process of optimization and understanding of physical systems in engineering applications as well as research.

It is assumed that students applying for the DS programme have basic knowledge in mathematics, physics and engineering at the level corresponding to the B.Sc. programme in Mechatronics Engineering of MCI or similar programmes at SDU or other universities in Denmark and abroad.

2. Programme structure and contents = context

The DS programme is structured into three groups of courses and projects that will be delivered in semesters 7, 8 and 9, followed by final project (see Table 1). These courses are profile courses such as MCIECS (Microcontroller and digital electronics – hands on), MCNCON (nonlinear control in engineering), and NAMMM2 (advanced mathematical methods to be used in .product development and mechatronic research). The profile courses link well to the other mechatronic courses such as NAFEA, MCMMM1, MCNUA.

Contents of the MCDPRO include deriving the Euler and Navier-Stokes equations being the governing laws of fluid transport. Special emphasis is given to acoustics and wave propagation through several

layers (transmission and reflection, waveguiding). The students subsequently develop their own computer codes in Matlab or other software and verify them against analytical models. In the second part of the MCDPRO course, the students learn basic piezoelectric theory and make their own transducer models in Matlab. A typical M.Sc. project in Dynamical Systems involve piezoelectric applications in transducers and hence links well to the sensor and actuator course as well as to the NAMMM2 course (numerical methods and analytical techniques).

The MCNCON course focuses on advanced nonlinear control models and requires MCMMM1. This course is highly relevant to research activities in Cybersailing, Energy Technology, and mathematical modelling applications in mechatronic systems.

NAMMM2 is the defining profile course of applied mathematical modelling. In this course, the students will learn how to attack problems in three dimensions effectively often with time as an extra dimension. The use of finite-element methods (NAFEA) is stimulated in project work. Furthermore, the philosophy of mathematical modelling, namely to simplify a mathematical problem as much as possible analytically before using computational techniques, is a core principle in NAMMM2.The final project for mathematical modelling students usually rely heavily on the NAMMM2 project.

Table 1

Semester	Courses / Projects	ECTS	Type
Semester 7	MCIECS	10	Profile Project
Semester 8 ***Use of mathematical modelling tools in mechatronic systems with control applications***	MCMMM1 MCDPRO	5 10	Programme Course Profile Project
Semester 9 ***Advanced Analytic methods and nonlinear control***	NAMMM2 MCNCON Thesis*	10 5 10	Profile Course Profile Course Final Project
Semester 10	Thesis	30	Final Project

* In the 9th semester, it is possible to choose between elective courses or commence on a 40 ECTS thesis to be completed in the 10th semester.

Table 1. M.Sc. Programme Framework

It is also possible to choose elective courses or carry out preliminary research and development, in preparation for the Final project executed in Semester 10.

3. Elective and specialized courses

Elective courses are complementary to the main courses presented above. These could be dedicated to important areas of research and development, e.g. intelligent sensors and actuators, nanotechnology and optics, waveguiding in different physical systems, fluid mechanics, heat transfer and thermal energy technology, digital signal processors, hardware/software co-design of embedded systems, etc., whenever these are not covered (sufficiently) by the main courses.

The list of elective courses will be updated every year, so as to closely follow the latest developments in the field of embedded control systems. Specialized courses may be delivered by industrial experts.

4. Course tracks

Coupling between courses and flexibility/links to other profiles:

The program course NAFEA on finite element modelling is a necessary prerequisite to follow the first mathematical modelling course MCMMM1. Similarly, the second mathematical modelling course NAMMM2 builds upon MCMMM1 and ultimately gives the student a strong general background in mecatronic systems mathematical methods of relevance in classical physics and refrigeration technology. MCMMM1 is also a prerequisite for control courses (e.g., MCNCON) and for physics oriented courses linking to the research profiles in mathematical-modelling based nanotechnology. The microcontroller and digital electronics course MCIECS requires good understanding of the mathematical theory behind filters and signal processing and hence links well to the other more general-based mathematics courses on the Dynamics Systems profile. The combination of mathematics courses and MCIECS reflects the skills required in many mechatronics applications.

Links to other courses in the mechatronics program of interest to DS profile students are courses related to software (in particular effective implementation of algorithms in component codes and system codes). Similarly, since many of our MM research activities are within the area of nanotechnology (electronic bandstructure theory, piezoelectrics, optics of nanostructures) there are close ties to the nanotechnology profile.

The Dynamic Systems profile has some overlap with the nanotechnology program, the new Thermal Energy Technology program, and the embedded software profile. This provides students with a background to follow courses across profiles for example as part of their elective courses.

DS courses will be attended by students who have graduated from the MCI with a B.Sc. or Dipl. Eng degree in Mechatronics, or an equivalent degree obtained from another university in Denmark or abroad. Therefore, they are expected to have different backgrounds, which may or may not require the inclusion of introductory projects (or the same kind of project) in the corresponding study programmes (tracks). Presently, three such tracks have been identified taking into account the background of expected applicants.

§10 Description of the profile:

Thermal Energy Technology

Introduction

Thermal systems are a broad class of mechatronic systems which covers a wide range of industrial applications. These ranges from e.g., thermal sensor and actuators, microprocessor cooling, cabinet freezers and refrigerators, air conditioning and heat pump systems to hypermarket heating, cooling and freezing, industrial systems and power plants, including thermal solar collectors and district heating or cooling networks. The continuing efforts for increased energy savings makes these highly energy consuming (or energy generating) areas an obvious candidate for increased attention.

Engineers with skills in both the mechatronic and thermal areas will be powerful candidates for handling the energy issues our community will face in the future. The mechatronic profile in Thermal Systems will provide the student with the basic theories and practical skills to; analyze and solve problems, develop concepts and products, and conduct and lead projects related to this technological area.

The courses are all based on ongoing research at MCI/SDU and students will be brought to research level in their field of specialization. The education is closely connected to the local cluster in refrigeration technology in southern Denmark and thesis projects are likely to be conducted in collaboration with local companies. In addition to employment in the energy technology sector or as consulting engineers, the masters in mechatronics from the thermal systems profile are likely candidates for a PhD study.

Competency goals

The thermal systems profile consists of lecture courses, seminars and semester projects delivered in the 7th, 8th and 9th semesters, respectively. After having successfully finished the program, the master student with specialization ‘Thermal Energy Technology Systems’ will have acquired expert knowledge within mechatronics and thermal systems including theoretical and practical skills on a civil-engineering level. The student is qualified to understand, disseminate and solve development tasks within mathematical modeling and simulation, process design and control of thermal systems and their components. Subsequently to understand, implement and participate in the execution of practical experiments in a project-based context. The student will be able to understand, reflect, disseminate and discuss scientific problems within thermal technologies. After the program the master student will be able to initiate and execute tasks and assume professional responsibility.

The primary competences are acquired in areas such as:

- Development methods and techniques for mathematical modeling of thermo-fluid components and systems
- Methods and techniques for control of components and systems in relation thermal systems
- Understanding thermal process and system design in a broad context
- Understanding procedures for design and implementation of experimental verification of theoretical models
- Use of advanced software technologies for development of modeling tools for thermo-fluid phenomena, systems and components
- Selection and use of components and technologies

- Dissemination of technical knowledge
- The ability to acquire life-long learning,
- Individual and group work process.

Context

The Thermal Systems Profile program consists of the courses listed in table 1.

Semester	**Courses / Projects**	**ECTS**	**Type**
Semester 7	Process Design and Analysis (MCPDA) Thermal and Fluid Dynamics (MCTFD)	5 5	Course Course
Semester 8	Practical Thermal project (MCTPRO) Mathematical Modelling (MCMMM1)	10 5	Project Course
Semester 9	Nonlinear Control (MCNCON) Mathematical Modelling of Heat Conduction (MCMMHC) Thermal Modeling Seminar (MCTMS) Thesis or electives (THS-U1/ELEC)*	5 5 5 10	Course Course Seminars Project
Semester 10	Thesis (THS-U2)	30	Project

* In the 9th semester, it is possible to choose between elective courses or commence on a 40 ECTS thesis to be completed in the 10th semester.

The **7th semester** profile courses are aimed at providing the students with the basic knowledge, methods and tools for the future program. The course MCPDA links closely with the MCCOS program course since MCCOS will provide the control tools for processes presented in MCPDA. MCPDA also links closely as a basic prerequisite to the MCTMS course on 9th semester. MCTFD is in a similar way

closely linked to these two courses (**on 9th semester**) since it constitutes the basic fundamentals for the physical processes in thermo-fluid components.

The two program courses NAFEA and MCNUA links in a similar way to both MCPDA, MCMMHC, MCTMS and the thesis project as they are generic courses in numerical tools.

The **8th semester** gives an opportunity for the students to conduct a practical project in the course TPRO, possibly in collaboration with local refrigeration companies. The skills and knowledge acquired in especially MCPDA, MCTFD and MCCOS is now put to practical use. MCMMM1 sets the mathematical foundation for the courses in the 9th semester.

In the 9th semester the previous courses are synthesized into the three research level courses: MCNCON, MCMMHC and MCTMS. MCNCON considers the state of art of handling complex control systems which can be highly relevant in e.g. process control. MCMMHC provides extended mathematical skills and background for detailed modeling of thermal systems and MCTMS gives the students a possibility of acquiring, analyzing and disseminating research level knowledge in thermal systems in a seminar form. The thesis preparation part, which can be substituted by elective courses, could be conducted in collaboration with a local refrigeration company.

Prerequisites

Students coming from our own mechatronics program will be able to attend the thermal systems profile. Students having another engineering bachelor degree or coming with a bachelor from another university should be proficient in English and have the basic mathematics and physics courses related to a mechanical engineering bachelor degree.

§11 Entry requirements

English Language Skills

Native English speaking applicants or applicants with a bachelor degree taught exclusively in English do not have to provide evidence of their English language skills.

Non-native English speaking applicants from a country within the European Union or the EEA are not required to pass an IELTS or a TOEFL test, if they can demonstrate knowledge of English corresponding with English at B level, as a minimum.

Applicants from a country outside the European Union or the EEA, however, must pass an IELTS or a TOEFL test with a minimum result of 6.5 in the IELTS test or a minimum result of 88 in the TOEFL test.

Bachelor Degree

Entry into the MSc (Eng) in Mechatronics programme requires one of the following bachelor degrees:

1. Bachelors with automatic claim for admission

BSc (Eng) in Mechatronics

Bachelors in Mechatronics from the Faculty of Engineering at the University of Southern Denmark have an automatic claim for admission on the Msc (Eng) in Mechatronics study programme.

2. Other qualifying bachelor exams from University of Southern Denmark

BEng in Mechatronics

Bachelors of Engineering in Mechatronics from the Faculty of Engineering at University of Southern Denmark are immediately entitled to admission for the MSc (Eng) in Mechatronics study programme.

BEng in Mechanical Engineering

Bachelors of Engineering in Mechanical Engineering from the Faculty of Engineering at University of Southern Denmark are immediately entitled to admission for the profiles Dynamic Mechatronic Systems, Nanotechnology and Thermal Energy Systems on the MSc (Eng) in Mechatronics study programme. Furthermore, Bachelors of Engineering in Mechanical Engineering from the Faculty of Engineering at University of Southern Denmark are entitled to admission for the profile Embedded Control Systems, provided that they take academic elements within electrical technology in the module ”Introduction to Embedded Control Systems” on 7th semester.

BEng in Computer Engineering, Electrical Power Engineering and Electric Engineering

Bachelors of Engineering in Computer Engineering, Bachelors of Engineering in Electrical Power Engineering and Bachelors of Engineering in Electric Engineering from the Faculty of Engineering at University of Southern Denmark are immediately entitled to admission for the profiles Embedded Control Systems, Nanotechnology and Thermal Energy Systems on the MSc (Eng) in Mechatronics study programme. Furthermore, Bachelors of Engineering in Computer Engineering, Bachelors of Engineering in Electrical Power Engineering and Bachelors of Engineering in Electric Engineering from The Faculty of Engineering at University of Southern Denmark are entitled to admission for the profile Dynamic Mechatronic Systems provided that they take academic elements within thermo dynamics and mechanics in the module ”Introduction to Embedded Control Systems” on 7th semester.

BEng in Civil Engineering

Bachelors of Engineering in Civil Engineering the Faculty of Engineering at University of Southern Denmark can be admitted on the profile Thermal Energy Systems following an individuel assessment, provided that they during their BEng study programme have specialised on climate control (heat – cooling) of buildings.

3. Other qualifying exams

BSc (Eng) and BEng from other universities

Bachelors of Science and Bachelors of Engineering from other Danish and foreign universities as well as other applicants with a corresponding education can be admitted to the study programme of MSc (Eng) in Mechatronics. Such an admission is subject to an assessment of whether the applicant's academic qualifications correspond to those of the abovementioned BSc (Eng) / BEng from the Faculty of Engineering at the University of Southern Denmark.

§ 12 External examiners and Study Board

The study programme belongs under the Academic Study Board of the Faculty of Engineering and the Danish corps of external examiners for engineering education.

§13 Entry into force and amendments

1. Approved by the Academic Study Board of the Faculty of Engineering and Director of Studies on behalf of the Dean on 23rd March 2010.

2. Study Start 2012 approved by the Academic Study Board of the Faculty of Engineering and Director of Studies on behalf of the Dean on 13th April 2012 (Version 1.0).