Electrical Engineering

/Elektro- och systemteknik/

The research area Electrical Engineering includes the following specialisations:

- **Electrical Engineering with specialisation in Computer Vision**/ Elektro- och systemteknik med inriktning mot datorseende/ SCB code: 10207/
- **Electrical Engineering with specialisation in Computer Engineering**/ Elektro- och systemteknik med inriktning mot datorteknik/ SCB code: 10206/
- **Electrical Engineering with specialisation in Integrated Circuits and Systems**/ Elektro- och systemteknik med inriktning mot elektroniska kretsar och system/ SCB code: 20299/
- **Electrical Engineering with specialisation in Vehicular Systems**/ Elektro- och systemteknik med inriktning mot fordonssystem/ SCB code: 21199/
- **Electrical Engineering with specialisation in Information Coding**/ Elektro- och systemteknik med inriktning mot informationskodning/ SCB code: 20204/
- **Electrical Engineering with specialisation in Communication Electronics**/ Elektro- och systemteknik med inriktning mot kommunikationselektronik/ SCB code: 20299/
- **Electrical Engineering with specialisation in Communication Systems**/ Elektro- och systemteknik med inriktning mot kommunikationssystem/ SCB code: 20203/
- **Electrical Engineering with specialisation in Automatic Control**/ Elektro- och systemteknik med inriktning mot reglerteknik/ SCB code: 20202/

General description of the research area

Electrical Engineering covers a broad spectrum of analysis, modelling, and design methods within control systems, electronics, communications, and computer vision. The subject has a solid foundation in mathematics and mathematical modelling of physical systems, and focuses on analysis and design of systems with industrially relevant applications. The subject is interdisciplinary in nature as the analysis and design of complex systems requires knowledge from several different areas. It is neighbouring other areas as well, especially within computer science as the design of complex systems includes partitioning and integration of hardware and software. The research education in Electrical Engineering aims to graduate technical licentiates and doctors with the ability to understand and develop methodologies in the field.

Eligibility requirements and selection

The basic eligibility requirements as well as the general principles for selection are specified in the faculty's *Study Handbook for PhD Studies*.

Specific eligibility requirements

Admission to PhD Studies in the research area of Electrical Engineering requires that the candidate has been awarded a degree of Master of Science in Engineering in a program related to the specialization, or has been awarded another master's degree in a field with comparable breadth and depth in the technical sciences.

Degree

PhD studies in Electrical Engineering leads to a Degree of Doctor or a Degree of Licentiate. The latter degree can also serve as a stage in the PhD studies. The Degree of Licentiate comprises 120 ECTS, of which courses correspond to 45-60 ECTS and the licentiate thesis corresponds to 60-75 ECTS. The Degree of Doctor comprises 240 ECTS, of which courses correspond to 90-120 ECTS and the doctoral thesis corresponds to 120-150 ECTS. The number of course credits will be specified when the PhD student's individual study plan is formulated.

Goals and implementation of the PhD studies

The general goals and objectives of PhD studies are specified in the introduction to the faculty's *Study Handbook for PhD Studies*, as well as in the Higher Education Ordinance (reprinted in the *Study Handbook*'s appendix A).

PhD studies in the research area of Electrical Engineering will equip the PhD student with the knowledge and skills to fulfill all the degree outcomes. The studies consist of research and thesis work, courses, participation in seminars, attendance at national and international conferences, and collaboration with industry.

The PhD studies will endow the PhD student with a broad knowledge and understanding of Electrical Engineering through participation in broadening courses at ISY and other departments, especially ITN, MAI, IDA, IFM and IEI, and by attending PhD courses in the respective specialisations.

The PhD student will acquire deep knowledge and understanding of Electrical Engineering and, in particular, his/her research specialisation by actively participating in some of the in-depth courses within his/her field of specialisation, by carrying out independent work in one or several research projects, by engaging in discussions at seminars and conferences and by participating in the collaboration with industry.

The PhD student will develop familiarity with scientific methodology through his/her own research, which can include theoretical calculations or laboratory experiments as well as industry collaboration, and by attending a mandatory course in research methodology.

PhD students in Electrical Engineering acquire skills and competencies by:

- Independently planning and carrying out both theoretical and experimental research work
- Regularly reporting on results achieved and plans for continued thesis work at the seminar series for the respective specialisations
- Participating in some of the large international conferences within the respective specialisations
- Taking advantage of international conferences as an opportunity to present his/her own research and thereby practise his/her ability to make presentations in front of colleagues from different fields of research, and to critically review both his/her own research and the other participants' research.

PhD students in Electrical Engineering will develop judgement and approach by completing courses in research ethics and by being confronted with practical problems in research and industry collaborations. PhD students in Electrical Engineering will demonstrate their intellectual autonomy by writing a monograph or compilation thesis.

Thesis

The thesis should as a rule cover a current topic in the respective specialisations, and the results that are included in the thesis should normally have been published in international journals of good repute and/or conferences. The thesis can be a monograph or compilation thesis.

Individual study plan

An individual study plan will be formulated for each PhD student. The detailed planning of courses and other components will be conducted in consultation with the supervisor and documented in the individual study plan (see *Study Handbook for PhD Studies*, section 5.3). The study plan should be established within one month after admission to PhD studies, and it should be revised at least once a year.

Supervision

The general rules for supervision can be found in Chapter 4 of the *Study Handbook for PhD Studies*, and in the *Policy for the Supervision of PhD Studies*.

Courses

The detailed planning of courses and other components will be conducted in consultation with the supervisor and documented in the individual study plan (see *Study Handbook for PhD Studies*, section 5.3).

Course content is chosen according to the PhD student’s specialisation. The courses that are offered in the various specialisations can vary from year to year in order to able to accommodate current research work. Courses can be taken individually or as a group. In the latter case, teacher-led seminars are often arranged. As a rule, one or two such seminar series are offered for each specialisation every academic year.

Besides courses within the research area and the specialisation, basic courses from other and adjacent, related fields are recommended, such as English, mathematics and computer science, where it is appropriate.

Of the required course credits, a smaller number of credits may be allocated to courses of a non-technical nature, such as research ethics and methodology, pedagogy, article writing, presentation techniques and English.

Courses can include project work, seminar courses and projects in collaboration with the industry.

Courses may even include:

- Undergraduate courses that were not part of the student’s undergraduate degree
- Course involving independent evaluation of literature in the field of research, which is submitted in the form of a report
- Short research projects (unrelated to thesis work)

Faculty course requirements

Scientific theory, methodology and ethics

All PhD students admitted starting 1 January 2010 should complete mandatory courses as decided by the faculty in methodology and ethics, or be deemed to have equivalent competencies, in order to receive a degree.

Pedagogic studies

All PhD students who teach should complete a basic course in pedagogy. At least 3 ECTS from this course should be included in the PhD studies, and any remaining credits should be counted as departmental duties (see *Study Handbook for PhD Studies*, section 5.5).

Course requirements for all specialisations

The following courses are of a more general character and are of broad interest within the research area. More specialised courses are indicated under the respective specialisations.

- Analog and Digital System Design
- Information Theory
- Communication Theory
- Convex Optimization
- Linear Systems
- Matrix Theory
- Signal Processing
- Signal Theory
- Technical Report Writing

Accreditation

Accreditation of components of the PhD studies is done in accordance with the *Study Handbook for PhD Studies*, section 5.6. Courses that fulfill the basic or specific eligibility requirements for admission to PhD studies may not be counted toward the degree being pursued in PhD studies.

Specialisations

Electrical Engineering with specialisation in Computer Vision

Computer Vision is a specialization within the area of computer and information processing, investigating systems and methods for automated processing and interpretation of image information. Research in this field aims to find effective methods and algorithms. The subject connects with a number of technical subjects such as artificial intelligence, machine learning, optimization, signal theory, control theory, statistics, and computer science. Important links also exist with non-technical subjects such as medicine, psychology, and biology. The problems studied within the field often include a combination of several of these subjects, giving the field an interdisciplinary character. The subject allows for specialization towards mathematical methodology as well as applied technology.

Specialisation-specific course requirements

For all the course requirements, please see the section on Degree above. Examples of typical courses in this specialisation:

- Robot Vision Systems
- Visual Object Recognition
- Geometry for Computer Vision
- Advanced Signal Processing Methods and Their Applications

- Visual Features and Clustering
- Neural Networks and Machine Learning
- Biological Vision Systems

Electrical Engineering with specialisation in Computer Engineering

Computer Engineering encompasses design and implementation of integrated circuits for data processing. The research in the area aims at developing methodologies for this purpose, from arithmetic circuits and architectures to algorithms and interfaces between hardware and software.

Specialisation-specific course requirements

For all the course requirements, please see the section on Degree above. Examples of typical courses in this specialisation:

- Advanced Computer Arithmetics
- Advanced Computer Architectures
- Distributed and Parallel Computer Systems
- Finite-Arithmetic Effects
- FPGA Design
- Integer- and Combinatorial Optimisation
- Embedded Systems
- Compiler Techniques
- Signal Processing
- System Design
- VLSI Implementation Techniques

Courses in fields of application and in related fields are recommended to the extent they are deemed appropriate.

Electrical Engineering with specialisation in Integrated Circuits and Systems

Integrated Circuits and Systems encompasses physical and technical aspects of analysis, design, and implementation of semiconductor components, integrated circuits, as well as systems composed of integrated circuits.

Specialisation-specific course requirements

For all the course requirements, please see the section on Degree above. Examples of typical courses in this specialisation:

- Advanced Electronic Components
- Design of High-Performance and Energy-Efficient Digital, Analog, and Radio IC Circuits
- Design of Data Converters and Mixed-Signal Circuits
- Low-Power IC Design
- Energy-Harvesting Circuits and Systems
- Sensor Circuits and Systems
- Avanced Radio Design

Electrical Engineering with specialisation in Vehicular Systems

Vehicular Systems encompasses control, diagnosis, and supervision of functions in vehicles. The approach is system based and covers for example utilization of physical models, simulation, sensors, and control, where several different techniques can be combined. The development of such systems requires a solid knowledge from several different areas such as control, mechanics, measurement technology, signal processing, thermodynamics, vehicle dynamics, computer science, and man-machine interaction. Central research topics in the area include methodology development and applications within diagnosis, modeling, vehicle propulsion, and behavior.

Specialisation-specific course requirements

For all the course requirements, please see the section on Degree above. Examples of typical courses in this

- Modeling and Control of Aftertreatment Systems
- Prognostics
- Turbocharging the Internal Combustion Engine
- Sensor and Measurement Technology for Engines
- History of Engines
- Non-Linear Observers
- Applied Thermodynamics
- Diagnosis
- Electrical Propulsion Systems
- Simulation of Ordinary and Differential-Algebraic Equations
- Numerical Optimal Control
- Internal Combustion Engine Fundamentals
- Vehicle Dynamics
- Statistical Inference
- Matrix Theory

Electrical Engineering with specialisation in Information Coding

Information Coding covers methods for efficient and secure representation and transmission of information. The subject has its ground in information theory but is inspired by other areas like signal theory, communication theory, encryption technology, quantum information theory, quantum communication, and computer graphics. Current research topics in the area include quantum informatics, communication security, video coding, and all-optical networks. The area is characterised by a strong international collaboration between different research and industrial groups. As a researcher in the area, one should be prepared to participate in such a collaboration at an early stage. This can be carried out through participation in an international project or in the form of a shorter or longer visit to a foreign research group.

Specialisation-specific course requirements

For all the course requirements, please see the section on Degree above. Examples of typical courses in this specialisation:

- Information Theory
- Signal Theory
- Communication Theory
- Signal Processing
- Quantum Computers
- Quantum Information Theory
- Coding Theory

- Advanced Video Coding
- Computer Vision
- Visual Perception
- Computer Architectures
- VLSI design

Electrical Engineering with specialisation in Communication Electronics

Communication Electronics covers high-frequency electronics for communication at low as well as high data rates. Different communication applications impose different requirements on the underlying technology. An example is wireless systems for sensor networks which have stringent requirements on the energy efficiency and robustness. In another case, the challenge can be to achieve data transmission at high data rates, which calls for systems that can handle complex modulated signal and broadband signals. The common factor between the different cases is that the efficiency per transmitted bit should be high. Research and development of high-frequency electronics, in particular in the gigahertz region, require design methodologies that take the wave propagation properties of the electronics into consideration. A solid knowledge of the physical properties of the material and components is an important part. Analysis of components and systems require computational models that incorporate electromagnetic properties.

Specialisation-specific course requirements

For all the course requirements, please see the section on Degree above. Examples of typical courses in this specialisation:

- Antenna Theory and Techniques
- Radio Frequency (RF) Electronics
- RF-System Development
- Microwave Techniques
- Wireless Sensor Networks
- Microcomputer/Embedded Systems
- Digital Communication Electronics
- Analog/Digital System Design
- Electromagnetic Compatibility and Printed Circuit Board Design

Courses in related fields, such as Integrated Circuits and Systems, Communication Systems and Information Coding, are recommended to the extent they are deemed appropriate.

Electrical Engineering with specialisation in Communication Systems

Communication Systems concerns all technical and methodological aspects of communication networks, particularly communication over wireless links and networks, and implementation aspects of technology used in such links and networks.

Specialisation-specific course requirements

For all the course requirements, please see the section on Degree above. Examples of typical courses in this specialisation:

- Communication Theory
- Wireless Communications
- MIMO Technology

- Detection and Estimation Theory
- Statistical Signal Processing
- Communication Networks
- Information and Coding Theory
- Efficient Algorithms and Implementation Aspects

Courses in related fields, such as Automatic Control, Electronics, Computer Engineering, Image processing and Coding, Antenna Technology, Statistics or Applied Mathematics, are recommended to the extent they are deemed appropriate.

Electrical Engineering with specialisation in Automatic Control

The fundamental problem in Automatic Control is to control a system using the feedback principle such that a desired behavior is achieved, despite disturbances acting on the system, limited a priori knowledge about the system and limitations of e.g. technical or economical character. The methods within the subject can, in addition to technical systems, be applied in a variety of fields such as e.g. economy and biological systems. The control field has connections to most engineering disciplines through its applications and also to subjects like production economy and biomedical engineering. The subject gives a general theoretical and methodological foundation concerning analysis of dynamical systems and is not connected to any particular application. The theoretical basis of the discipline has close connections to the fields Mathematics, Mathematical Statistics, Optimization, and Computer Science. The main research areas within the discipline are modelling and identification of dynamical system, signal processing with emphasis on sensor fusion, robotics and autonomous systems, and optimization for control applications in e.g. model predictive control.

Specialisation-specific course requirements

For all the course requirements, please see the section on Degree above.

The following basic courses for this specialisation are as a rule offered every second year:

- Linear Systems
- System Identification
- Nonlinear Control
- Robust Multivariable Control

The aim of these courses is to provide a broad and solid base in Automatic Control. For a Degree of Doctor, three of these courses should be completed, and for a Degree of Licentiate, two of these courses should be completed.

Examples of typical selectable courses in this specialisation:

- Linear Estimation
- Signal Processing
- Adaptive Filtering and Fault Detection
- Hybrid Systems
- Adaptive Control
- Modelling
- Optimal Control
- Applied Control

- Convex Optimisation
- Tracking
- Modelling and Control of Industrial Robots

PhD students in Automatic Control are also encouraged to broaden their expertise by studying PhD courses at for example the Department of Mathematics and the Department of Computer and Information Science.

Transitional provisions

Changes to the general study syllabus do not apply to those who have already been admitted to PhD studies in the research area. A change to the new general study syllabus may however be approved if both the main supervisor and the PhD student agree. In such a case, this should be documented in the individual study plan.