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1. General information

Title/name of the study programme: Electrical Engineering
Type of study programme: postgraduate doctoral study programme
Level of the study programme: Level III
Duration of the study programme: 3 years (6 semesters)
Number of ECTS credits: 180
Research discipline: engineering and technology
Academic degree: doktor / doktorica znanosti
Abbreviation of the title: dr. in front of the name

The duration of the postgraduate doctoral study programme of Electrical Engineering is three years, it comprises 180 ECTS credits and is, according to the Bologna scheme, a programme of the 3rd level of higher education. Study obligations are evaluated by the European Credit Transfer System (ECTS), which provides the basis for international exchange of students in countries using the same or a comparable credit system.

The study programme of Electrical Engineering inseparably connects the studies with scientific research and development work. The programme mainly focuses on independent creative research work of students, who are guided by their mentors.

The programme gives priority to optional choice over obligatory forms of studies. In order to adequately cover the increasingly ranified field of modern electrical engineering, the choice of study contents is wide and versatile. The possibility of choosing gives students the opportunity to plan their research careers and follow the needs of future employers as soon as possible. Furthermore, through obligatory seminars and integration of elective generic contents (transferable skills), we offer an appropriate breadth of education. The programme enables mobility in the framework of both organised forms of study and individual research work.

During the studies students are expected to actively participate at Slovenian and international scientific and specialist workshops and conferences. In this way students can develop the skills of scientific communication, critical assessment of the achievements of others and of the results of their own research work. The key obligations of students include the proposal and preparation of the doctoral dissertation. In the doctoral work, in addition to demonstrating their capacity for thinking in a scientific manner and their aptitude for research work, the candidates also give proof of original contributions to science, which are usually published in international scientific publications indexed by SCIE.
2. Aims of the programme and competences acquired

The main aim of the doctoral study programme of Electrical Engineering is to educate independent researchers with broad specialist skills and in-depth basic methodological knowledge.

General aims of the programme

– To inseparably link the studies with scientific research and development work.
– To develop a scientific approach and to master scientific thinking.
– To encourage comprehensive understanding of electrical engineering and its role in the broader scientific context.
– To encourage students to follow and master of state-of-the-art methods and technologies.
– To develop communication skills, skills of reporting on scientific research achievements and skills of transferring knowledge.
– To develop an objective and critical evaluation of achievements of others and of one’s own results.
– To prepare doctoral degree holders for creative scientific research and development work in the field of electrical engineering and broader.

General competences acquired through the programme

– Competence for individual creative scientific research and development work in the field of electrical engineering and broader.
– Competence for following and accurately evaluating the latest achievements in the broader field of electrical engineering.
– Critical evaluation of the results of one's own research and development work.
– Competence for active professional written and oral communication.
– Competence for team work with experts from various fields.
– Professional, environmental and social responsibility.

Subject-specific competences acquired through the programme

– Deepening of fundamental knowledge in electrical engineering.
– To conduct independent creative scientific research and technology development, specifically in:
  - electric energy, photovoltaic,
  - electronics, microelectronics, optoelectronics, micro electromechanical systems, and nanostructures,
  - mechatronics, embedded systems, intelligent, control systems, and robotics,
  - metrology, and quality engineering,
  - biomedical engineering and informatics,
  - information, communication, and multimedia technologies.
– Supplementing the existing knowledge with knowledge from complementary fields and with general skills.
3. International projects

In 2013, the Faculty participated in 30 EU projects: 14 projects of the Seventh Framework Programme (FP7), 4 projects of the COST programme, 3 projects of the TEMPUS programme, 3 projects of the Metrology Research Programme (EMRP), 2 projects of the SEE programme and 1 project of each of the following programmes: AAL, ALPINE SPACE, CIP, INTERREG and IPA. The funding received in 2013 for the implementation of these projects at the Faculty was **EUR 1.32 million**.

In 2013, the Faculty also participated in **12 bilateral projects** with research institutions from **8 foreign countries**. Compared to 2012, when there were as many as 26 bilateral projects, this represents a marked decrease, resulting mostly from the significantly reduced scope of published bilateral projects by the Slovenian Research Agency.

4. Research programmes

In 2013, the Faculty was involved in 15 research programmes of the Slovenian Research Agency (ARRS) with total programme funding of **EUR 1.59 million** or **27.43 FTE** (in 2012, EUR 1.58 million or 27.09 FTE). The Faculty coordinates or autonomously conducts 12 research programmes and participates in 3 research programmes coordinated by the Jožef Stefan Institute. The Faculty also runs the infrastructural centre of the Laboratory of Biocybernetics (1 FTE) as part of the infrastructure programme Network of Research Infrastructure Centres at the University of Ljubljana (MRIC UL). In 2013, five research programmes came to a close; however, based on the public call to submit research programmes for the next funding period and reports on the results of the research programmes, all of these programmes have been reselected for funding over the next 3–6 years.

In 2013, a total of 37 research projects of the Slovenian Research Agency (ARRS) were active: 18 basic projects, 15 applied projects and 4 post-doctoral projects. For 6 of these 37 projects, funding ended in 2013, but as many as 13 of the projects were new, with an implementation starting date of 1 August 2013 and funding until 31 July 2016. For 21 projects, the Faculty acted as an autonomous contractor or a coordinator. The volume of project funding by the Slovenian Research Agency in 2013 amounted to **EUR 784 thousand** or **14.23 FTE**, which, despite the successful acquisition of new projects, represents a continued and marked trend of reduced funding for the research projects of the Slovenian Research Agency (in 2012: EUR 930 thousand or 17.7 FTE; in 2011: EUR 1.1 million or 18.5 FTE). In 2014, the funding of as many as 18 projects of the Slovenian Research Agency will end. Therefore, despite the planned applications in the upcoming public calls, a drop in the volume of annual research project funding can be realistically expected this year too.

5. Structure of the programme and study guidelines

**Structure of the programme**

The duration of the doctoral study programme of Electrical Engineering is three years, it comprises 180 ECTS credits and is, according to the Bologna scheme, a programme of the 3rd level of higher education. The programme consists of organised forms of study and individual research work, both of which are evaluated with ECTS credits. The structure of the study programme is presented in Table I.
The first year focuses on organised studies in the form of lectures and seminars, the second and the third year of the programme are entirely devoted to research work and the preparation and presentation of the doctoral dissertation. One semester comprises 30 ECTS credits, one year 60 ECTS credits and the entire doctoral study programme 180 ECTS credits. Organised study comprises 60 ECTS credits; the other 120 ECTS credits are awarded to research work and the doctoral dissertation. An ECTS credit is evaluated with 25 hours of students' work. The total number of all study obligations thus equals 750 hours per semester, 1500 hours per year and the entire study programme amounts to 4500 hours of study obligations.

### Table I

<table>
<thead>
<tr>
<th>1st year: organised forms of studies 30 ECTS credits</th>
<th>2nd year: organised forms of studies 10 ECTS credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st semester: organised studies 15 ECTS credits</td>
<td>2nd semester: organised studies 15 ECTS credits</td>
</tr>
<tr>
<td>Course unit</td>
<td>Course unit</td>
</tr>
<tr>
<td>Subject A</td>
<td>Subject C</td>
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<tr>
<td>E, S</td>
<td>E, S,</td>
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<tr>
<td>Subject B</td>
<td>Subject D</td>
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<td>5</td>
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<tr>
<td>Research work</td>
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<td>15</td>
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<tr>
<td>Seminar (Report on research work)</td>
<td>Seminar (Report on preparation for the topic of the doctoral dissertation)</td>
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<tr>
<td>S, O</td>
<td>S, O</td>
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<tr>
<td>5</td>
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<tr>
<td>Total</td>
<td>Total</td>
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E: elective; S: specialist; G: generic; O: obligatory; M: mobility

<table>
<thead>
<tr>
<th>2nd year: organised forms of studies 10 ECTS credits</th>
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<td>Research work</td>
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<td>Total</td>
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</table>

<table>
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<th>3rd year: organised forms of studies 20 ECTS credits</th>
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</thead>
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<tr>
<td>5th semester</td>
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<tr>
<td>CR</td>
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<td>Research work</td>
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<tr>
<td>Doctoral dissertation</td>
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<tr>
<td>Total</td>
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</table>

### Study plan

Before enrolling in the programme, students choose a mentor, who advises them on the selection of subjects and guides them through the studies. Together with their mentor, students select four subjects. The seminars are obligatory for all students of the doctoral study programme of Electrical Engineering. The main component of the studies is independent research work for the doctoral dissertation.
**Elective subjects**

All subjects are elective. Students choose two to four subjects corresponding to 10 to 20 ECTS credits (1st and 2nd semester) among the offered specialist subjects (see Table II) according to the research field of their doctoral dissertation. All subjects are worth 5 ECTS credits.

**Transferable skills**

The Faculty of Electrical Engineering at the University of Ljubljana offers one elective subject of communication skills in a scientific work (marked with an asterisk in Table II), which is also included in the *Generic subjects unit within the Doctoral school of the University of Ljubljana*. Students can choose up to 5 ECTS credits worth of general contents or one general subject (1st semester).

**Mobility**

Together with their mentor, students can select up to 10 ECTS credits worth of study contents from other doctoral study programmes at the University of Ljubljana and from comparable programmes of other universities (1st and 2nd semester). Students can attend two semesters at another university (up to 60 ECTS credits), so that they can complete one third of their study obligations elsewhere.

**Seminars**

The seminars (1st and 2nd semester) are compulsory for all doctoral students of Electrical Engineering and are worth 5 ECTS credits each. Seminars are conducted by mentors. Students present the results of their work in written and oral form. Seminars require attendance at presentations by other students and participation in discussions. This ensures the extension of studies beyond the field of the doctoral dissertation as well as interaction between doctoral students.

In the first semester students prepare an overview of the field of their research work. In the second semester, doctoral students report on the preparation of the subject of their dissertation. This ensures an additional time check and a timely approach to dissertation planning.

**Research work for the doctoral dissertation**

Research work is devoted to the preparation and completion of the doctoral dissertation. It is evaluated with 120 ECTS credits. This includes individual scientific research work directed by the mentor. Research work requires active participation at Slovenian and international scientific and specialist meetings.

**Doctoral dissertation proposal**

By the end of the 4th semester, students should prepare the proposal of the subject of their doctoral dissertation, which includes an appropriate breakdown of the subject, its incorporation into the field of the research work, an indication of the expected contribution to science, which should be methodologically supported with initial results. Students present the subject of their dissertation in public. The preparation and presentation of the doctoral dissertation are evaluated with 10 ECTS credits.
Doctoral dissertation

As a rule, students complete and publicly present their doctoral dissertation – which together comprises 20 ECTS credits – by the end of the 6th semester. In the doctoral work, in addition to demonstrating their capacity for thinking in a scientific manner and their aptitude for research work, the candidates also give proof of original contributions to science, which are usually published in international scientific publications indexed by SCIE.

The doctoral dissertation is an original contribution to science, which is prepared in accordance with the provisions of the Statute of the University of Ljubljana and the Rules on doctoral studies.

Mentorship

The mentor for preparation of the doctoral dissertation is a person with a corresponding academic title (Assistant Professor, Associate Professor, Professor) or a scientific worker with attested research activity and corresponding bibliography from the field of the doctoral dissertation. Students choose their mentor at their discretion before or upon enrolment. The responsibility of the mentor is guiding the student through the studies (selection of subjects, seminars, proposal and composition of the doctoral dissertation and ensuring working conditions for the work with research equipment, typically in the mentor’s lab.

Students can choose a different mentor by the beginning of the 3rd semester. In this case the student should inform their earlier mentor and the Vice Dean for research and development activities in writing about the change, for which the new mentor must give his or her consent. After the beginning of the 3rd semester the potential change of mentor is discussed by the Commission for scientific research on the basis of a well-founded request of the student. Co-mentorship is recommended in the case of interdisciplinary or multi-institutional researches. Co-mentorship is deliberated by the Commission for scientific research.

List of elective subjects

Table II.

K1. Department of Fundamentals of Electrical Engineering, Mathematics and Physics

<table>
<thead>
<tr>
<th>Course coordinator</th>
<th>Lecturers</th>
<th>Course unit code</th>
<th>Course Title</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Dolinar Gregor</td>
<td>prof. dr. Gregor Dolinar izr. prof. dr. Emil Žagar izr. prof. dr. Gašper Pijavž</td>
<td>64801</td>
<td>Selected topics in Mathematics</td>
<td>5</td>
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<tr>
<td>02 Sivnik Tomaž</td>
<td>izr. prof. dr. Tomaž Sivnik</td>
<td>64802</td>
<td>Electrical properties of plasmas and introduction to controlled fusion</td>
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<tr>
<td>03 Iglič Aleš</td>
<td>prof. dr. Aleš Iglič prof. dr. Veronika Kralj – Iglič</td>
<td>64803</td>
<td>Electrostatics of Surfaces and Nanostructures</td>
<td>5</td>
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<tr>
<td>04 Križaj Dejan</td>
<td>prof. dr. Dejan Križaj izr. prof. dr. Anton Sinigoj izr. prof. dr. Iztok Humar</td>
<td>64804</td>
<td>Elektromagnetics</td>
<td>5</td>
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<tr>
<td>05 Slivnik Tomaž</td>
<td>prof. dr. Tomaž Slivnik</td>
<td>64805</td>
<td>Computational elektromagnetics</td>
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K 2. Department of Power Systems and Devices

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<td>06 Bizjak Grega</td>
<td>prof. dr. Grega Bizjak</td>
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<td>Intelligent buildings</td>
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<td>07 Mihalič Rafael</td>
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<td>Energy Conversions and Environment</td>
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<tr>
<td>08 Pantoš Miloš</td>
<td>izr. prof. dr. Miloš Pantoš</td>
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<td>Power System Operation in Market Environment</td>
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<td>09 Papič Igor</td>
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<td>64809</td>
<td>Active distribution networks</td>
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<td>10 Čepin Marko</td>
<td>izr. prof. dr. Marko Čepin</td>
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<td>Reliability in electrical power engineering</td>
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## K 3. Department of Electronics

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<tr>
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<td>Možek Matej Doc. dr. Matej Možek</td>
<td>64811</td>
<td>Sensors and Actuators</td>
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<td>12</td>
<td>Topič Marko prof. dr. Marko Topič prof. dr. ir. Miro Žeman</td>
<td>64812</td>
<td>Photovoltaics</td>
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<td>13</td>
<td>Smole Franc prof. dr. Franc Smole</td>
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<td>Nanoelectronics</td>
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<td>14</td>
<td>Krč Janez prof. dr. Janez Krč</td>
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<td>Optoelectronics</td>
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<td>Tuma Tadej prof. dr. Tadej Tuma</td>
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<td>Optimization in Electronic Design Automation</td>
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<td>16</td>
<td>Žemva Andrej prof. dr. Andrej Žemva izr. prof. dr. Andrej Trost</td>
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<td>Digital electronic systems design</td>
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## K 4. Department of Measurement Systems

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<tr>
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<td>Agrež Dušan izr. prof. dr. Dušan Agrež</td>
<td>64870</td>
<td>Measurement dynamics and techniques of electromagnetic compatibility</td>
<td>5</td>
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<tr>
<td>18</td>
<td>Bojkovski Jovan izr. prof. dr. Jovan Bojkovski</td>
<td>64818</td>
<td>Virtual measurement systems</td>
<td>5</td>
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<td>20</td>
<td>Kamnik Roman prof. dr. Roman Kamnik</td>
<td>64823</td>
<td>Intelligent mobile transport systems</td>
<td>5</td>
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<td>21</td>
<td>Mihelj Matjaž prof. dr. Matjaž Mihelj prof. dr. Robert Riemer</td>
<td>64824</td>
<td>Multimodal interactive 3D technologies</td>
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<td>22</td>
<td>Munih Marko prof. dr. Marko Munih prof. dr. Jadran Lenarčič</td>
<td>64825</td>
<td>Selected topics in robotics</td>
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## K 5. Department of Microelectronics

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<td>Pieteršek Anton izr. prof. dr. Anton Pieteršek</td>
<td>64827</td>
<td>Integrated Microsystems SoC and analog-digital integrated circuits</td>
<td>5</td>
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<tr>
<td>24</td>
<td>Strle Drago izr. prof. dr. Drago Strle izr. prof. dr. Anton Pieteršek</td>
<td>64828</td>
<td>Advanced Microelectronic systems: selected topics</td>
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## K 6. Department of Mechatronics

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<td>Fišer Rastko izr. prof. dr. Rastko Fišer prof. dr. Vanja Ambrožič</td>
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<td>Electrical servo drives in mechatronics</td>
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<td>26</td>
<td>Miljavec Damijan prof. dr. Damijan Miljavec</td>
<td>64830</td>
<td>Modern electric machines</td>
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<td>Vončina Danijel prof. dr. Danijel Vončina izr. prof. dr. Peter Zajec</td>
<td>64832</td>
<td>Control of Electronically Commutated Motors</td>
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## K 7. Department of Systems, Control and Cybernetics
K 8. Department of Information and communication Technologies

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<td>35 Humar Iztok</td>
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<td>Telecommunication system design and management</td>
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<td>36 Kos Andrej</td>
<td>prof. dr. Andrej Kos</td>
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<td>Systems for processing large amounts of data</td>
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<tr>
<td>38 Pogačnik Matevž</td>
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<td>5</td>
</tr>
<tr>
<td>40 Vidmar Matjaž</td>
<td>prof. dr. Matjaž Vidmar</td>
<td>64875</td>
<td>Modern design of radio communications</td>
<td>5</td>
</tr>
<tr>
<td>41 Zajc Matej</td>
<td>izr. prof. dr. Matej Zajc</td>
<td>64876</td>
<td>Ambient intelligence in multimedia environments</td>
<td>5</td>
</tr>
</tbody>
</table>

K 9. Department of Biomedical Engineering

<table>
<thead>
<tr>
<th>Course coordinator</th>
<th>Lecturers</th>
<th>Course unit code</th>
<th>Course Title</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>42 Likar Boštjan</td>
<td>Prof. dr. Boštjan Likar</td>
<td>64851</td>
<td>Imaging Technologies</td>
<td>5</td>
</tr>
<tr>
<td>43 Jarm Tomaž</td>
<td>izr. prof. dr. Tomaž Jarm</td>
<td>64881</td>
<td>Measurement and processing of biomedical signals</td>
<td>5</td>
</tr>
<tr>
<td>44 Kotnik Tadej</td>
<td>Prof. dr. Tadej Kotnik</td>
<td>64880</td>
<td>Microbioelectromagnetics</td>
<td>5</td>
</tr>
<tr>
<td>45 Pernuš Franjo</td>
<td>Prof. dr. Franjo Pernuš</td>
<td>64882</td>
<td>Medical Image Analysis</td>
<td>5</td>
</tr>
</tbody>
</table>

6. Admission requirements and enrolment criteria

Enrolment criteria

The following candidates can enrol in the postgraduate doctoral studies of Electrical Engineering:
– graduates of postgraduate master study programmes,
– graduates of study programmes providing education for occupations regulated by Directives of the European Union evaluated with at least 300 ECTS credits,
– graduates of university study programmes established before 11. 6. 2004,
− graduates of postgraduate study programmes for obtaining a Master’s degree established prior to the Bologna reform. The fulfilled study obligations of these candidates are recognised to the extent of 90 ECTS credits,
− graduates of specialist study programmes after university programmes, established before 11. 6. 2004. The fulfilled study obligations of these candidates are recognised to the extent of 60 ECTS credits,
− graduates of specialist study programmes after the higher education, established before 11. 6. 2004. Additional study obligations, four compulsory courses and two elective courses of the first year postgraduate study programme in Electrical engineering amounting to 36 ECTS credits, are determined by the commission nominated by the Faculty of Electrical Engineering,
− graduates of equivalent study programmes at other universities. The equivalence of the obtained education abroad is determined in the process of recognition of education abroad for the continuation of education, in accordance with Article 121 of the Statute of the University of Ljubljana.

Selection criteria when enrolment is restricted
The selection of candidates will be based on the success in postgraduate master studies as follows:

<table>
<thead>
<tr>
<th>Grade point average in postgraduate master studies, or grade point average of university study programmes established before 11. 6. 2004, excluding thesis and defence assessment.</th>
<th>grade x 7</th>
</tr>
</thead>
</table>

In case of restricted enrolment the candidates with more points will be accepted.

7. Criteria for recognising knowledge and skills acquired before enrolment in the programme

Knowledge and skills acquired by formal, informal or empirical learning will be recognized in case of restricted enrolment in accordance with Article 9 of the Criteria on accreditation of study programmes. The body deciding on recognition of knowledge and skills acquired before enrolment in the programme is the Commission for scientific research. The factors taken into account when deciding on the recognition of such knowledge and skills are: specialization, another degree at a higher education institution, the existing scientific research work, published scientific works, professional training.

8. Methods of assessment

In accordance with Article 132 of the Statute of the University of Ljubljana the performance at examinations is assessed with grades from 1 to 10, positive grades being 6 – 10. Details about the assessment of knowledge are regulated by the Examination rules of the Faculty of Electrical Engineering at the University of Ljubljana. The programme includes written and oral exams and the assessment of the preparation and presentation of a seminar. Methods of assessment are described in detail under individual course syllabi.

Candidates receive the proposed number of ECTS credits for a course if they perform successfully at the required knowledge assessment for that particular course.
9. Requirements for progression through the programme

- Requirements for progression to the 2nd year of the doctoral studies are the completed study requirements worth a total of at least 50 ECTS credits.
- For progression to the 3rd year of the postgraduate doctoral studies students must have completed all study obligations of organised forms of studies from the first two years of their studies.
- The last, third year is intended for research work and the preparation and defence of the doctoral dissertation.

10. Provisions on changing programmes

Termination of the student’s education in the study programme in which he/she enrolled and the continuation of the studies in the doctoral study programme of Electrical Engineering is regarded as transfer between programmes. Students’ applications for transfer to the doctoral study of Electrical Engineering will be – in accordance with Articles 181-189 of the Statute of the University of Ljubljana – separately dealt with by the Commission scientific research of the Faculty of Electrical Engineering.

11. Mode of study

Doctoral Programme of Electrical Engineering is implemented as a part-time study.

12. Requirements for completion of the programme

Requirements for completion of the study programme and for acquisition of the academic title of Doctor of Science are: successfully completed all study obligations determined by the programme and the successfully defended doctoral dissertation, which together is worth 180 ECTS credits. Candidates for the doctoral degree should also have at least one published scientific article in a magazine indexed by SCIE, the candidate being the first author. The scientific article should be published or accepted for publication prior to submission of the dissertation for assessment. Completing individual parts of the programme is not possible.
13. Short presentation of subjects

<table>
<thead>
<tr>
<th>Subject Description</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>01</strong> Selected topics in Mathematics</td>
<td></td>
</tr>
<tr>
<td>Functional analysis:</td>
<td></td>
</tr>
<tr>
<td>-metric spaces (notion of distance, properties of metric spaces, examples of different metrics on vector spaces and on functional spaces)</td>
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<tr>
<td>-normed vector spaces (notion of norm, relations between norms and metrics)</td>
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<tr>
<td>-spaces with scalar product (Hilbert space)</td>
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<tr>
<td>-bounded linear operators, matrices (contraction mapping principle and fixed point, spectral theory, eigenvalues and eigenvectors)</td>
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<td>-wavelets</td>
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<tr>
<td>Discrete mathematics:</td>
<td></td>
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<tr>
<td>-graphs, basics</td>
<td></td>
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<tr>
<td>-matchings and coverings in bipartite graphs, duality, Hall marriage condition, stable matchings</td>
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<tr>
<td>-flow problems in networks, maximum flow and minimum cut, Ford/Fulkerson theorem, duality, flow integrality</td>
<td></td>
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<tr>
<td>-linear programming, simplex method, primal and dual programs, applications</td>
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<tr>
<td>Numerical solution of partial differential equations by the finite element method:</td>
<td></td>
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<tr>
<td>-finite element method for second order boundary value problem</td>
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<tr>
<td>-variational (weak) form of the problem (appropriate functional spaces, equivalence of classical and variational form)</td>
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<tr>
<td>-discretization (triangulation, bases with local support, matrix form notation)</td>
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<tr>
<td>-numerical integration</td>
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<tr>
<td>-numerical solution using FreeFEM++ open source package</td>
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<tr>
<td><strong>02</strong> Electrical properties of plasmas and introduction to controlled fusion</td>
<td></td>
</tr>
<tr>
<td>Definitions of the Debye length, plasma parameter, plasma frequency</td>
<td></td>
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<tr>
<td>Motion of a charged particle in electric and magnetic field</td>
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<tr>
<td>Diffusion in a plasma and plasma conductivity</td>
<td></td>
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<tr>
<td>Kinetic and hydrodynamic description of a plasma</td>
<td></td>
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<tr>
<td>Basic MHD equations and some fusion oriented examples</td>
<td></td>
</tr>
<tr>
<td>Plasma waves</td>
<td></td>
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<tr>
<td>Binary interactions (collisions)</td>
<td></td>
</tr>
<tr>
<td>Introduction to fusion, fusion reactions, power balance, magnetic and inertial confinement</td>
<td></td>
</tr>
<tr>
<td>Nonlinear phenomena: sheaths, electric probes</td>
<td></td>
</tr>
<tr>
<td>Introduction to particle-in-cell computer simulations of bounded plasma systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Piel, Plasma physics – An introduction to laboratory space and fusion plasmas, Springer 2010</td>
</tr>
<tr>
<td></td>
<td>R. W. Hockney, J. W. Eastwood, Computer simulation using particles, IOP publishing, 1994</td>
</tr>
<tr>
<td><strong>03</strong> Electrostatics of Surfaces and Nanostructures</td>
<td></td>
</tr>
<tr>
<td>Thermodynamic description of systems with a large number of particles, theoretical description of electrolyte solution in contact with charged surface (electric double layer theory), dielectric properties of electric double layer, electrostatics of nanostructures, adsorption of charged nanoparticles on charged surfaces, influence of charged nanoparticles on mediated interactions between charged surfaces, interaction of charged nanoparticles with nanostructured metallic and/or semiconductor surfaces</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Aktualni znanstveni članki iz področja, ki jih sproti določijo izvajalci predmeta</td>
</tr>
</tbody>
</table>
### Electromagnetics

The course is constructed of three parts:

1. Theoretical part in which we repeat Maxwell’s laws in integral form and transform them to a differential one. Poynting theorem, Helmholtz equation, Green formulation are introduced. Mathematical formulation of electromagnetic field for numerical computation is analysed.

2. Aspects of numerical simulations in electromagnetics are discussed (possible simplifications, boundary conditions, discretization of equations, meshing, methods for numerical computation).

A concrete practical example of an electromagnetic structure is analysed and suitably modelled using computational tools for numerical simulations in electromagnetics.

**Readings**

- [www.comsol.com](http://www.comsol.com)

### Computational electromagnetics


**Readings**


### Intelligent buildings

The course concentrates on humans and their needs in working and living environment. Different ways of making working and living in interiors more friendly, comfortable and safe are presented with the help of selected chapters from building automation and lighting. Special emphasis will be given on safety and energy efficiency of buildings.

Content is divided in the following sections:

- Human needs at work and living
- Building automation
- Intelligent Installation
- Lighting on a human scale
- LEDs and other modern light sources
- Use of daylight
- Energy efficient and environmentally friendly "green" buildings
- Measurements and sensors
- Building connections with the outside world

**Readings**

3. SCHERG, Rainer. EIB/KNX_Anlagen, Vogel Buchverlag, 2011
5. VALBERG, Arne. Light Vision Color, John Wiley & Sons, Ltd, 2005
07 Energy Conversions and Environment

The role of energy-sources exploitation in the development of human civilisation and society. A global view of the problems of energy supply, and the factors influencing energy-consumption needs. The basic physical laws of energy conversion and the technologies for primary energy-sources exploitation (trends in development). The environmental and social acceptability of energy-conversion technologies. Dilemmas and the technical problems of covering energy needs, applying renewable energy sources, and a comparison with classical technologies. The environmental impact of energy conversions – facts or fashion trends. The rational use of energy vs. "saving regardless of costs". Strategic trends and regulations in the EU in the field of energy supply. Economic assessment of meeting energy needs (economic assessment of various solutions and energy-saving measures). Looking to the future.

Readings


David J. C. Mackay Sustainable Energy — without the hot air, electronic copy is provided, free, for personal use only. See www.withouthotair.com, Slovene version: Energetika.NET, Ljubljana 2013

08 Power System Operation in Market Environment

Impact of electricity market on power system operation: the role of producers, consumers, transmission and distribution networks and their technical constraints, methods for static analyses, sensitivity analyses, optimal power flow calculation. Ancillary services: load forecasting, reserves, active power and frequency control, reactive power and voltage control, methods for voltage collapse proximity assessment, ancillary service procurement. Power system reliability, security of supply, reliability indices, network adequacy. Deterministic and stochastic concepts in power system operation and energy markets.

Readings

1. Gubina F., Delovanje elektroenergetskega sistema, Založba ULFE, 2006
6. B. J. C. MacKay Sustainable Energy — without the hot air, electronic copy is provided, free, for personal use only. See www.withouthotair.com, Slovene version: Energetika.NET, Ljubljana 2013

09 Active distribution networks

Consequences of growing environmental concern, general lack of energy resources in western Europe, availability of new technologies for production of electrical energy, penetration of distributed energy resources – DER in distribution networks. Gradual transition of classical passive distribution network into an active network with resources on the consumption side, specification of the concept of an active distribution network. Overview of distributed energy resources, interconnection requirements and assessment of potential in Slovenia. The influence of distributed energy resources on the operation of a distribution network: voltage profile, power flows, reactive power, power quality, protection, control, maintenance and planning. Key technologies enabling the operation of an active distribution network: energy resources with control capabilities, energy storage systems, modern compensation devices, advanced information and communication technologies. Readings


10 **Reliability in electrical power engineering**

Basic principles of reliability, safety, risk and their mutual relationship.
Basics of probability theory, set theory and Boolean algebra.
Measures of reliability and safety of facilities and devices. Risk criteria. Risk informed decision making.
Methods for assessment reliability and safety – theory and examples: loss of load probability, distribution indices (system average interruption frequency index, system average interruption duration index), effective load carrying capability, fault tree, event tree.
Common cause failures – methods and examples.
Improvement of reliability of power systems and devices: redundancy, independence, separation, fail-safe principle, single failure criterion.
Readings


11 **Sensors and Actuators**

Sensor definitions, transduction principles, classifications of sensors and actuators.
Essential sensor properties: characteristics, sensitivity, accuracy, resolution, selectivity, minimal detected signal, threshold, nonlinearity, repeatability, noise, temperature zero drift, overload, stability, analysis of sensor dynamic response.
Review of standard silicon microelectronic technologies: Micromachining: basic materials properties, deposition, etching, LIGA, sacrificial film, laser application, opening sealing, substrate bonding, sensor chip encapsulation/packaging, 3D structures fabrication
Analog and digital signal conditioning in sensor and actuator systems.
Review of sensor and actuator structures and applications: Piezoresistive, Piezoelectric, Pyroelectric, Capacitive, Resonant, Thermoelectric, Radiation, Magnetic, Chemical, Optical fiber
Advanced sensor and actuator structures.
Readings


12 **Photovoltaics**

Solar energy and review of conversion concepts to electrical energy.
Solar cells: principles of operation, structures, materials and technologies, properties of crystalline silicon and gallium arsenide cells, thin-film (silicon, chalcopyrite, cadmium telluride), mesoscopic and organic solar cells; tandem and multijunction solar cells; thermophotovoltaic cells; analysis of optical and electrical losses, modeling, simulations and characterization; advanced concepts and technological trends.
Photovoltaic systems: grid-connected and stand-alone PV systems; design and planning, operation and maintenance; power regulators and inverters, protection elements; energy storage concepts; reliability and maintainability; grid-connection, economics of PV systems.
Readings

13 **Nanoelectronics**


Readings


14 **Optoelectronics**

**INTRODUCTION:** current challenges and trends in Optoelectronics

**OPTICS:** models of light, light and matter, complex permittivity and complex refractive index, reflection on flat and rough interfaces, refraction, scattering, photometry and radiometry

**OPTICAL SOURCES:**
- Light emitting diodes (LED): spontaneous emission, materials, structures, technologies, optical and electrical characteristics
- Organic LED (OLED): materials, structures and trends
- Lasers: stimulated emission, operational principle and requirements, main parts of a laser, optical amplification and losses, spectrum and shape of the output beam, applications of lasers
- Laser diodes (LD): structures, PN, DH, DBR, DFB VCSEL LD, applications, power LD

**PHOTODETECTORS and COLOUR DETECTORS:**
- Semiconductor photodetectors (pn, pin, heterodiode, avalanche, phototransistor), optical filters, vertical thin-film colour detectors based on a-Si:H
- Detector arrays: CCD, CMOS and a-Si:H detector arrays

**DISPLAYS:** structure and operation of LCD, properties and characteristics of TFTs, LED, plasma and OLED displays, 3D displays

**OTHER SELECTED TOPICS:** photonic crystals, nanophotonics, plasmonics, printed optoelectronics, metamaterials, optical antennas, optical sensors, Fourier optics

The contents of the course is being updated and upgraded with seminar works on specific topics on optoelectronics and photonics.

Readings


15 **Optimization in Electronic Design Automation**


Readings


Web page of SPICE OPUS ([www.spiceopus.si](http://www.spiceopus.si))
### Digital electronic systems design


Hardware/Software co-design and system modeling using high-level languages: SystemC, SpecC, UML. Feasibility analysis and systems partitioning to hardware and software. Optimization of hardware and software system parts.


Readings

### Measurement dynamics and techniques of electromagnetic compatibility

Amplitude and time dynamics of the generalized measurement channel: signal conditioning, sampling, and quantization. Uncertainty principles: the time-frequency uncertainty and the time-amplitude uncertainty. The principle of the limited signal decreasing and leakage effect. Analysis of the characteristic parameters of the measurement signals and systems in the time, frequency, and information domain. Measurement and estimation of the basic periodic parameters (frequency, amplitude, and phase) in the time and frequency domain in the presence of noise. Comparison of the measurement uncertainties with the theoretically achievable Cramér-Rao bounds.

Electromagnetic compatibility of system, sources and suppression of disturbances. The process measurement system sensitivity to measurement, influence, and disturbance quantities. Coupling mechanisms to external sources: galvanic, capacitive, inductive, and electromagnetic coupling. Methods of improving the response of the measurement systems with hardware and software. Hardware approach: shape the impulse response of the front stages, symmetry of the inputs, shielding and grounding in the measurement systems. Software approach: filtering, averaging, modulation, and analysis with discrete Fourier transformation.

Selected topics on hardware and software dynamics for acquisition, conversion and estimation of the process quantities. Automatic acquisition of the measurement data and their processing with computers.

Readings
Virtual measurement systems
- Basic concepts of virtual measurement instrument
- Software for programming virtual measurement instruments, graphical programming, data flow concept
- Hardware for virtual measurement instruments, communication bus, plug in data acquisition board
- Basic of data acquisition
- Synthetic measurement instruments
- Control of virtual instruments via TCP/IP network
- Automation of measurement laboratory based on the central database approach
- Development of Virtual instruments – good practice guides
- Methods of testing and validation of virtual measurement instruments, limitation of software testing
- Software quality and other quality standards
- Reliability of software
- Advanced software testing techniques
- How to prepare good test case
- Different testing methods
[1] Open source code and quality (Linux, BSD, Android, ...)
Readings

Metrology and Quality Systems
International standardization and compatibility of products, services and processes for regulated and voluntary field: basic principles of metrology systems and standardization, organization of the accreditation organization, certification systems, review of European technical legislation, control and analyses of active quality systems, ISO and EN standards, basic knowledge on preparation of laboratories. Development and realization of basic SI units, physical constants, hierarchical organisation of metrology systems, international compatibility, metrology development, elements of formal measurement theory, symbolical representation, information contents, measurement theory, measurement error and measurement uncertainty analyses, classification of errors, calibration, etalons, basic of quantum metrology, reference materials, processing and evaluation of measurement results, testing, calibration, measurement system parameters. Quality control, quality assurance, total quality assurance, quality costs, bad quality costs, organizational knowledge, business functions and processes, administration management, decision-making, coordination, systems and planning techniques, quality information systems, products and services quality. Become aware of modern quality assurance techniques with examples of interlaboratory comparisons, risk assessment in testing procedure evaluation and preparation of optimal experiment. The process of adopting new standards in the field of medical instrumentation (procedures, clinical validation, risk analysis).
steady state heat transfer and heat balance,
heat transfer (conduction, convection, radiation), heat transfer through walls (planparallel, cylindric), temperature and temperature scales (realization and dissemination), thermometers (resistance, thermocouples, liquid-in-glass, radiation, thermal imagers), energy efficiency of buildings (design, insulation, ventilation, heating, cooling, calculation, measurement, energy certificate)
Readings

Information Booklet
### 20 **Intelligent mobile transport systems**


Readings:

### 21 **Multimodal interactive 3D technologies**

Psychophysiology of human visual, auditory and haptic sensing; Methods for modelling and rendering of three-dimensional stimuli of all three modalities (visual, auditory and haptic); Collision detection between complex virtual objects; Technologies for spatial presentation of synthesized 3D stimuli (stereoscopic and holographic displays, spatial sound generation, haptic robots for presentation of kinaesthetic and tactile stimuli); Technologies and methods for user movement tracking that enable interaction with the environment and navigation within the environment; Augmented reality as interaction with real and telepresence as interaction with remote environment through digital medium; Analysis of users’ psychophysiological responses and strategies for real time adaptation of virtual environment based on users’ psychophysiological state; Use of interactive 3D technologies in areas such as product design, sales and marketing, architecture and design, education, medicine, research and development.

Readings:

### 22 **Selected topics in robotics**

- Analysis and synthesis of serial and parallel robot mechanisms
- Advanced approaches in kinematics, dynamics, control and sensory systems in robotics
- Parallel robot systems: kinematic singularities, manipulability, sensitivity of constructional errors
- Robotic grasping systems: multifinger robot grippers, grasping in man and robot, tendon systems
- Robot systems in medicine: rehabilitation robotics, robotics in surgery, irobotics
- Walking robots: monopod, biped, and multilegged robots, analysis and synthesis of locomotion in man and robot
- Exotic robots

Readings:
5. *Springer Tracts in Advanced Robotics* (several books)

### 23 **Integrated Microsystems SoC and analog-digital integrated circuits**

The student selects one of the following modules:

A. SoC design and nanoelectronic circuits – Modeling of sensors and nanostructure design, Trends in advanced mixed integrated circuits design in nano-technologies. Problems and solutions in modern sub-micron and nano circuits, Solving small tasks in circuit design with extreme short-channel MOSFETs with structure sizes of about and below 90nm, Overview of nanoelectronics.

B. Advanced analog/digital integrated circuit and SoC—selections – Concept of sensors integration in SoC; Project managing and case study from selected areas – System specifications, Device specifications, Test specifications (UHF systems on chip, optoelectronic integrated circuits (OEICs), Integrated magnetic systems, Systems with chemical sensors, Smart active/passive labels technology (SAL), Protocols integration, UHF-GEN2 and MEMS technology).

C. Industrial and intellectual property, basics of marketing techniques – Intellectual property, Protection of intellectual property. Understanding and implementing the marketing process for technical products, Design effort, NRE, royalties, Cost of ASIC processing, MPW and MLM cost, dedicated MLM versus MPW, cost of wafers; market and competitors.

D. SoC evaluation and testing technology – Build-in tests, System knowledge needed, SoC testing and product evaluation methods, Yield, Thyrister effect, ESD protection, solutions and testing for EMI, Quality control, Burn-in testing, Reliability improvement, Wafer testing, Modern packaging technologies, Flip-chip and wafer-bumping technologies, Failure analysis.

Readings:


24 Advanced microelectronics systems: selected topics

The course is continuation of content of subject Microelectronic systems. The content includes modern innovative architectures of mixed signal analogue/digital integrated systems in deep sub-micro-meter CMOS and BiCMOS technologies (<90nm) with all restrictions and modelling problems related to modern technologies. Problems related to complexity and low supply voltage require special attention for digital, analogue and mixed-signal circuit implementation. Important part is built-in-self-test (BIST) and cointegration fo sensors and electronics. The course will be divided in three main directions:

- The design of low/high voltage integrated systems including high frequency and low noise dynamic systems in CMOS and BiCMOS technologies,
- Cointegration of MEMS/NEMS sensors together with VLSI integrated system including also modelling and verification methodologies
- Testing of modern complex microelectronic systems including BIST methods for mixed-signal integrated systems

Each direction is based on the lectures, followed by seminar work, which is the basis for the individual research work.

Readings

25 Electrical servo drives in mechatronics

The overview of methods and procedures for control of modern servo drives with AC machines: induction, synchronous (with surface-mounted and buried magnets) and reluctance machines. Controlled drives in mechatronics (speed control in current supplied electrical machines; field oriented control – FOC; direct torque control – DTC). Problems concerning robustness of the control considering incorrectly identified and/or fluctuating parameters of the drive. Position and/or speed sensorless methods in AC drives. Sensorless control. The application of observers and MRAS in servo drives. Application of modern microprocessors in dynamically demanding electrical controlled systems: tasks, problems, configurations, software.


Design principles of energy efficient electric motors, control of electrical drives in energy saving regime. On-line condition monitoring and diagnostics of electrical drives, early detection of electrical and mechanical faults of AC motors and power converters, application of artificial intelligence methods in integrated approach to control and supervision of modern servo drives.

Readings
### Modern electric machines


**Readings**

5. P. S. Bimbhra, Generalized Theory of Electric Machinery, Khanna Publishers, Delhi, 2004

### Power Electronics Converters

Nowadays, study of power electronics is not focused only on the generally known criteria list the power converters should comply with: loss reduction, increase of their specific power, estimation of their useful lifetime and the production cost. Increasingly important is to understand their roles in connecting complex systems for the efficient conversion of energy from renewable sources in electricity and its further efficient conversion and end-use in systems such as: smart heating/cooling, hybrid vehicles, smart grids.

**Detailed content:**

1. Insights into modern solid-state power switches and the challenges they face e.g. heat dissipation and reduction of parasitic inductions. Overview of main challenges and study of specific attempts in integration of the converter components into a unified whole (systemically and geometrically). Study of mechanisms of excess heat dispersal, reduction of mutual electromagnetic influence, achieving an appropriate dielectric strength and reliability.
2. Practical design issues, such as snubbers, semiconductor stresses due to the high slope of current and voltage, losses and efficiency.
3. Review of basic modulations (PWM, vector control and others) and related solutions specific to the operation near to the margins (in terms of low duty cycle) of existing semiconductor switches. Various control of semiconductor converters. Predictive and repetitive control methods in power electronics.
4. Effects of power converters to the supply grid voltage and to the adjacent electronic devices. Study of electromagnetic compatibility problems: sources of electromagnetic (EM) emissions, modes of coupling and reduction techniques of EM emissions. Setups for measuring radiated and conducted emissions.
5. Overview and analysis of modern designs in the case of specific converter topologies (serial / parallel multi-cell converter design, serial / parallel connection of power switches, combining different modes of operation).
6. System-oriented analysis of operating conditions, stability conditions in selected state of the art converter systems and subsystems. Performing sensitivity analysis to assure various control and power flow aspects (distortion, resonance mitigation).

**Readings**

5. Žbirke publikacij: IEEE.org (Power Electronics, Industrial Electronics, Control Systems, Power&Energy Society)

### Control of Electronically Commutated Motors


**Readings**

### Selected Topics of Complex Systems Control Design

Contents of the course will concentrate mainly to the following:

- **Introduction to complex systems** (description and mathematical representation of complex systems: model uncertainty, multivariable and large-scale systems, systems with time-delays, non-minimum-phase systems, nonlinear and time-varying systems, combined continuous – discrete event systems)
- Presentation of performance limitations using **analysis**
- Presentation of corresponding **control design** approaches, which include also the concepts of optimal control strategies (in implicit or explicit manner):
  - optimal control problem (principles and criteria, linear quadratic controller, state observers, combination of optimal control with modern design methods), adaptive control design, hierarchical and distributed control, network control systems,
- Results extension to expert system development

**Control implementation technology** for complex systems (computer control systems and programmable logic controllers, corresponding software, network technologies, industrial information systems).

**Readings**


### Machine Vision

Modelling of visual systems: physical, mathematical, biological and computational basics. Selected mathematical tools and algorithms for analysis of visual information: selected topics from linear algebra, stochastic systems and information theory.

Selected algorithms for detection and tracking of objects, events, for motion analysis and activity, based on visual information. Multi-sensor visual systems. Biologically motivated architectures for visual sensing. Visual sensor networks and embedded visual systems. Machine vision in industry, visual inspection and measurement.

Machine vision in advanced visual surveillance systems, biometric systems and robots. Use of machine vision in sport, analysis of individual and team activities. Machine vision in advanced user interfaces.

**Readings**


### Advanced Control of Autonomous Systems

- Introduction to autonomous systems – mobile systems, unmanned aerial vehicles, space crafts
- Methods for localisation and mapping, simultaneous localisation and mapping, extended Kalman filter, position, orientation and feature estimation methods - particle filter
- Higher level control – strategies of multi-agent systems control
- Path planning – the principle of optimality, path optimisation with constraints (obstacle avoiding, nonholonomity, dynamic constraints, actuator constraints), satellite orbits
- Optimal control in the presence of disturbances
- Frequency domain robust control design methods
- Trajectory tracking control of autonomous systems
- Control of autonomous systems to the final state
- Adaptive control of autonomous systems
- Matrix inequality control of autonomous systems

**Readings**

### 32 Stochastic Processes and Signals

**Introduction:**
- Definition of stochastic process and random signal. Introduction of some important issues from mathematical modeling in statistics and probability theory.

**Random signals processing:**
- Time and sample mean, random signals filtering (Wiener and Kalman filter), probability distribution evaluation (Expectation-Maximization (EM), Maximum A Posteriori (MAP) and »Maximum Likelihood Linear Regression« (MLLR) procedures)

**Modeling of stationary and non-stationary stochastic processes:**
- Gauss process, Poisson process, Gauss-Markov process, non-stationary stochastic processes representation using Hidden Markov Models (HMM)

Examples from speech signals processing, modeling of speech perception and production: source-filter model for speech production, speech perception model and deconvolution of speech signals, time-frequency representations of speech signals, speech detection, speech signal modeling using HMM.

Readings:

### 33 Pattern recognition

- **Introduction:** definitions, pattern representations, pattern recognition by classification and analysis, applications of pattern recognition in economy, traffic, medicine, robotics, banking, forensics, man-machine communication, etc.
- **Pattern pre-processing:** restoration, enhancement, normalization.
- **Pattern segmentation:** basic idea, image segmentation, and auditory signals segmentation.
- **Features:** generation of features by heuristic and mathematical methods.
- **Analysis of learning sets:** pattern similarity measures, pattern clustering test, crisp and fuzzy clustering, clustering techniques, deep learning of generative models.
- **Pattern classification:** classification of feature vectors by matching, decision, inference, and artificial neural networks; classification of sequences by dynamic programming and Hidden Markov Models; classification by graph matching; classification of statistically dependent samples.

Combining and fusing classifiers.

Readings:

### 34 Advanced intelligent control systems


Readings:
### Telecommunication system design and management

Extended knowledge of telecommunication system design, modelling planning, simulation, emulation and management of telecommunication systems and services.


Telecommunication traffic, load, application and element measurements and characterization. Characteristics modeling, evaluation and understanding their influences on system’s performances. Conformance testing and verification of telecommunication systems. Management and control of telecommunication systems. Management models, protocols and information models. Accounting and billing.

Energy and cost efficiency of telecommunication systems, optimization approaches. Techno-economic aspect of telecommunication system design.

#### Readings

1. Humar I., Better J.: Načrtovanje, razvoj in upravljanje telekomunikacijskih sistemov (v pripravi)
6. Iversen V. B.: Teletraffic Engineering and Network planning, Technical University of Danmark, jan. 2007

### Systems for processing large amounts of data

Data collection: smart phones, sensors and internet-connected devices, web, cleaning and preparation of data, data anonymization and de-identification.

Data retention: scalable relational databases, NoSQL databases, understanding the compromise between the consistency of data, performance and availability.

Data processing: event-oriented processing, processing parallelization (map-reduce), extraction of structured data from unstructured.

Analyses: efficient algorithms for processing and analysis of data, machine learning visualization, procedures and challenges of visualizing large amounts of data, other modalities of presentation of data (soundification, etc.).

Applications of the presented techniques: systems for context detection, smart systems (applications of smart cities, smart transport, etc.), medical applications, social networks, financial systems.

#### Readings

2. Tom White: Hadoop: The Definitive Guide, 3rd Edition; Storage and Analysis at Internet Scale; O'Reilly Media
6. Scott Murray: Interactive Data Visualization for the Web: An Introduction to Designing with D3, O'Reilly Media
37 **Operations research**

Algorithms, time and memory complexity, data structures. Graph theory (representation, selected graph properties, basic graph algorithms).


Readings


38 **Interactivity and user experience in multimedia systems**

Introduction: Building blocks, architectures and services in interactive multimedia systems

Interactivity: Principles of interactivity and interaction modalities (voice, gestures, different devices and controls, second screen).

User devices and sensors (advanced I/O interaction devices). Technology aspects of integrating the interactive control devices with multimedia services.

The user experience: the importance of good user experience, design and evaluation of user interfaces and user experience (user-centered design). Specifics of different user groups. Adapting services and interfaces to users and context of use (personalization).

Readings

1. Vaughan T.; Multimedia: Making it work, McGraw-Hill Osborne media; 2010
3. Albert W., Tullis T.; Measuring the user experience: collecting, analyzing, and presenting usability metrics; Elsevier, 2013.

39 **Human – machine interaction**

Human perception and its limitations (human senses, memory and emotions). User interfaces (visual, auditory, tactile, biometrics, natural interfaces). Elements of interaction (models of interaction, hard and soft controls, natural and learned interaction, mental models and metaphors, navigation, context and errors). User centred design of user interface (hierarchical tasks analysis, requirements specification, prototyping). Evaluation of user interface through a user study (methodology, experiment design, independent and dependent variables, objective and subjective evaluations, test subjects, analysis of results).

Readings


40 **Modern design of radio communications**

Introduction to radio communications. Basic radio communication systems and sub-systems: sources (transmitters), media, drains (receivers), antennas. Modern antenna design with the appropriate numerical tools (2D, 2.5D and 3D). Millimetre, sub-millimetre and terahertz antennas. High-frequency electrical circuit design. High-frequency properties of passive and active devices. Modern modelling of linear and nonlinear high-frequency circuits. High-frequency measurements. Ground-based and satellite communications. Limitations, properties and design of satellite communications.

Readings

Ambient intelligence in multimedia environments

Smart multimedia sensors with the ability to capture, store, and process audio and video signals for situation recognition and implicit interaction purposes. Intelligence of natural and artificial systems. Human-centric interaction allowing users an easy access to multimedia environments (search, exploration, manipulation and control of media and devices). Multi-modality: utilization of various categories of sensors (camera, microphone, accelerometer, etc.). Multi-device interaction. Visualization and animation of sensing, decisions, and implicit interactions supporting users understanding and prediction of system’s behaviour. Evaluation of different advanced multimedia approaches for interaction, e.g., gesture, touch, tangible interaction. Implementation issues of real-time multimedia system. Applications, ambient technologies, ambient games, ambient intelligent environments for education, ambient presentation of arts and cultural heritage.

Readings

Imaging Technologies

Image acquisition techniques: digital photography, cameras and illumination units for visible and invisible part of the electromagnetic spectrum, microscopy, radiography, computed tomography, magnetic resonance imaging, ultrasonic imaging, advanced and emerging imaging techniques.

Methods for image restoration, calibration, processing, analysis, integration, measuring and understanding of image content - with the emphasis on robustness, reliability, stability and applicability in real-time.

Design, integration and application of imaging technologies and computer and machine vision systems - in everyday life, in industry and in biomedicine - for the extraction of multidimensional information about the inspected space, objects and subjects.

Readings

Medical Image Analysis

1. Introduction: history, importance and areas of computer-aided analysis of medical images.
2. Medical image sources: X-ray imaging, computed tomography, magnetic resonance imaging, ultrasound, nuclear medicine and molecular imaging.
3. Image segmentation and quantitative analysis: classification and applicability of methods, (adaptive) thresholding, edge-based segmentation techniques, region growing, segmentation with clustering, deformable models, atlas based methods. Validation of image segmentation methods.
4. Image registration: clinical applications of image registration, classification of registration methods, spatial transformation models, within- and across-modality registration, landmark based registrations, surface based registrations, intensity based registrations, similarity measures. Validation of registration methods.

Image guided procedures: tracking devices, visualization in image-guided procedures, planning, registration of preoperative images, models and plan with intraoperative images, 3D-2D registration, validation of image guided procedures, clinical applications.

Readings
Microbioelectromagnetics

2. Analytical derivation of induced membrane voltage in static electric fields: spherical cells (Schwan equation), cylindrical, spheroidal and ellipsoidal cells.
4. Analytical derivation of voltage induced on membranes of intracellular organelles. Ratio between the voltage induced on the external and membrane and the internal membranes.
5. Numerical computation of induced membrane voltage in static electric fields: dense suspensions of spherical cells, irregularly shaped cells, clusters of electrically insulated and electrically connected cells.
7. Molecular dynamics simulations: lipid bilayered in the electric field, formation and resealing of transmembrane pores.

Electroporation in nature and its possible role in the evolution of microorganisms. Three biochemical mechanisms of horizontal gene transfer. Lightning as the cause of DNA release from irreversibly electroporated microorganisms, movement of released DNA in aqueous environment (electrophoresis) and DNA uptake by reversibly electroporated microorganisms.

Readings

Measurement and processing of biomedical signals

Advanced overview of selected signals of biological origin encountered in research or in medical clinical environment. Physiological origin and typical properties of these signals. Physical background and application of methods for acquisition and measurement of these signals. Electrodes and probes for acquisition of non-electrical quantities. Signal processing methods in time and frequency domain for extraction of clinically or experimentally relevant information about the biological system. Concrete examples of application.

The signals of these origins are to be discussed: electrophysiological signals (electrocardiography, electromyography of skeletal and smooth muscles, electroencephalography, nerve conduction); blood flow (ultrasound, laser Doppler); oxygenation (near infrared spectroscopy and methods for oximetry); measurement of biological cell properties (microscopy and spectroscopy).

Readings
Izbrani članki iz znanstvenih revij/Selected papers from scientific journals
## List of lecturers

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<th>Lecturers</th>
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<td>1. Agrež Dušan</td>
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<td>Atanasijević-Kunc, Maja</td>
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<th>4.</th>
<th>Begeš, Gaber</th>
<th>Metrology and Quality Systems</th>
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BEGEŠ, Gaber, DRNOVŠEK, Janko, PENDRILL, L. R. Optimising calibration and measurement capabilities in terms of economics in conformity assessment. Accreditation and quality assurance, ISSN 0949-1775, Mar. 2010, vol. 15, no. 3, str. 147-154  

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<th>5.</th>
<th>Bizjak, Grega</th>
<th>Intelligent buildings</th>
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4. BIZJAK, Grega, KOBAV, Matej Bernard, YLINEN, Anne- |


6. Blažič, Sašo
   Selected Topics of Complex Systems Control Design

7. Blažič, Sašo
   Advanced control of autonomous systems

8. Bojkovski, Jovan
   Virtual measurement systems
| ID 6333268 |

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<td>1. GRUENWALD, Johannes, TSKHAKAYA, David, KOVAČIČ, Jernej, ČERČEK, Milan, GYERGYEK, Tomaz, IONITA, Codrina, SCHRITTWIESER, Roman. Comparison of measured and simulated electron energy distribution functions in low-pressure helium plasmas. Plasma sources sci. technol., 2013 vol. 22, str. 015023 (7 strani)</td>
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<th>11. Dobrišek Simon</th>
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### Doctoral Programme Electrical Engineering

**Information Booklet**

**University of Ljubljana**  
**Faculty of Electrical Engineering**

**ISSN 0340-6253, 2014, vol. 71, no. 1, str. 199-212.**


FIJAVŽ, Gašper, WOOD, David Richard. Graph minors and minimum degree. The Electronic journal of combinatorics, ISSN 1077-8926. [Online ed.], 2010, vol. 17, no. 1, r151 (30 str.).

FIŠER, Rastko, LAVRIČ, Henrik, BUGEZA, Miroslav, MAKUC, Danilo. Computations of magnetic field anomalies in synchronous generator due to rotor excitation coil faults. IEEE transactions on magnetics, ISSN 0018-9464, May 2013, vol. 49, no. 5, str. 2303-2306, ilustr. [COBISS.SI-ID 9822548]


### 15. Fišer Rastko  
**Electrical servo drives in mechatronics**


GERŠAK, Gregor, DRNOVŠEK, Janko. Avtomatski merilniki krvnega tlaka za domačo uporabo - ali jim lahko zaupamo? = Automatic blood pressure measurement devices for home use - can we trust them ?. Zdravniški vestnik, ISSN 1318-0347.

### 16. Geršak Gregor  
**Metrology and Quality Systems**

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HUMAR, Iztok, BEŠTER, Janez, POGAČNIK, Matevž, MEŽA, Marko. Extending differentiated services with flow rejection mechanism for wireless IP environments. Elektrotehniški vestnik, ISSN 0013-5852. [Slovenska tiskana izd.], 2005, letn. 72, št. 1, str. 30-35, ilustr. [COBISS.SI-ID 4771668]
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27. Kralj-Iglič Veronika Electrostatics of Surfaces and Nanostructures


28. Krč Janez Optoelectronics

| KOVAČIČ, Milan, KRČ, Janez, LIPOVŠEK, Benjamin, TOPIČ, Marko. Diffraction gratings for optical filtering in...
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<td>Matko Drago</td>
<td>Advanced control of autonomous systems</td>
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<th>Mihalič Rafael</th>
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<th>36.</th>
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37. Mihelj Matjaž  | Multimodal interactive 3D technologies |
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38. Milevec Damijan  | Modern electric machines |
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<td>3. VIDMAR, Gregor, PFAJFAR, Jurij, AGREŽ, Dušan,</td>
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| 2. | RESNIK, Drago, VRTAČNIK, Danilo, ALJANČIČ, Uroš, MOŽEK, Matej, AMON, Slavko | Experimental study of Ti/Pt...

40. Munih Marko
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41. Mušič Gašper
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<th>Pantoš Miloš</th>
<th>Power System Operation in Market Environment</th>
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<td>ŠMON, Ivan, PANTOŠ, Miloš, GUBINA, Ferdinand. An improved voltage-collapse protection algorithm based on local...</td>
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46. Perš Janez  
Medical Analysis  
Image


47. Perš Janez  
Machine vision

1. MANDELJ, Rok, KOVAČIČ, Stanislav, KRISTAN, Matej, PERŠ, Janez. Tracking by identification using computer vision and radio. Sensors, ISSN 1424-8220, Jan. 2013, vol. 13, no. 1,
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<td>2.</td>
<td>PLETERŠEK, Anton, TRONTELJ, Janez</td>
<td>A self-mixing NMOS channel-detector optimized for mm-wave and THZ signals.</td>
<td>Journal of infrared, millimeter, and terahertz waves</td>
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48. Pletersk Anton

**Integrated Microsystems SoC and analog-digital integrated circuits**


2. **PLETERŠEK, Anton, TRONTELJ, Janez.** A self-mixing NMOS channel-detector optimized for mm-wave and THZ signals. *Journal of infrared, millimeter, and terahertz waves*, ISSN 1866-6892, 2012, vol. 33, no. 6, str. 615-626. [Link](http://www.springerlink.com/content/622t346575715452/fulltext.pdf)


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49. Pletersk Anton

**Advanced Microelectronic systems: selected topics**


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ZEMLJARIČ, Borut, SINIGOJ, Anton R. Magnetno in električno polje v okolici daljnovodnega stebra. Elektrotehniški vestnik, ISSN 0013-5852. [Slovenska tiskana izd.], 2009, letn. 76, št. 1/2, str. 69-74, ilustr. [COBISS.SI-ID 7238740],  
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56. Sodnik Jaka

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57. Strle Drago

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58. Škrjanc Igor

Advanced intelligent control systems


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2. L. Pavlovič, M. Vidmar, S. Tomažič, 10 Gb/s 2^{15}-1 pseudo-random binary sequence generator (Pseudonaključni podatkovni izvor z bitno hitrostjo 10 Gbit/s in dolžino zaporedja 2^{15}-1), Informacije MIDEM, ISSN 0352-9045, jun. 2012.


63. Vončina Danjel  Power Electronics Converters


64. Vončina Danjel  Control of Electronically Commutated Motors

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<td>Zajec, Peter</td>
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3. PETKOVŠEK, Marko; KOSMATIN, Peter; ZEVNIK, Ciril; VONČINA, Danijel; ZAJEC, Peter. Measurement system for testing of bipolar plates for PEM electrolyzers, Informacije MIDEM, ISSN 0352-9045, mar. 2012, letn. 42, št. 1, str. 60-67. [COBISS.SI-ID 9277012]
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8. Zeman, Miro: Optical model for multilayer structures with coherent, partly coherent and incoherent layers, OPTICS EXPRESS Vol: 21 Issue: 5 Pages: A262-A267 Published: 2013
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