# Recomended pass through the study plan

## Name of the pass: Branch Senzors and Instrumention - Passage through study

Faculty/Institute/Others: Faculty of Electrical Engineering
Department:
Pass through the study plan: Cybernetics and Robotics - Senzors and Instrumention
Branch of study guranteed by the department: Welcome page
Guarantor of the study branch:
Program of study: Cybernetics and Robotics
Type of study: Follow-up master full-time
Note on the pass:

**Coding of roles of courses and groups of courses:**
**P - compulsory courses of the program, PO - compulsory courses of the branch, Z - compulsory courses, S - compulsory elective courses, PV - compulsory elective courses, F - elective specialized courses, V - elective courses, T - physical training courses**

**Coding of ways of completion of courses (KZ/Z/ZK) and coding of semesters (Z/L):**
**KZ - graded assesment, Z - assesment, ZK - examination, L - summer semester, Z - winter semester**

### Number of semester: 1

| Code | Name of the course / Name of the group of courses<br>*(in case of groups of courses the list of codes of their members)*<br>*Tutors, **authors** and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| BEZM | **Safety in Electrical Engineering for a master´s degree**<br>*Vladimír Kůla, Radek Havlíček, Ivana Nová, Josef Černohous, Pavel Mlejnek **Radek Havlíček** Vladimír Kůla (Gar.)* | Z | 0 | 2BP+2BC | Z | P |
| B3M35LSY | **Linear Systems** | Z,ZK | 8 | 4P+2C | Z | P |
| B3M38VBM | **Videometry and Contactless Measurement** | Z,ZK | 6 | 2P+2L | Z | PO |
| B3M38ZDS | **Analog Signal Processing and Digitalization** | Z,ZK | 6 | 2P+2L | Z | PO |
| 2015_MKYRVOL | **Volitelné odborné předměty** | Min. cours.<br>0 | Min/Max<br>0/999 | | | V |

### Number of semester: 2

| Code | Name of the course / Name of the group of courses<br>*(in case of groups of courses the list of codes of their members)*<br>*Tutors, **authors** and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| B3M33ARO | **Autonomous Robotics** | Z,ZK | 7 | 3P+2L | L | P |
| B3M38DIT | **Diagnostics and Testing**<br>*Radislav Šmíd **Radislav Šmíd** Radislav Šmíd (Gar.)* | Z,ZK | 7 | 3P+2L | L | P |
| B3MPVT | *Pavel Mužák, Tomáš Drábek, Martin Hlinovský, Ondřej Drbohlav **Tomáš Drábek** Tomáš Drábek (Gar.)* | KZ | 6 | 0P+4S | L | P |
| B3M38VIN | **Virtual Instrumentation**<br>*Antonín Platil, Jaroslav Roztočil **Antonín Platil** Antonín Platil (Gar.)* | Z,ZK | 6 | 2P+2L | L | PO |
| 2015_MKYRVOL | **Volitelné odborné předměty** | Min. cours.<br>0 | Min/Max<br>0/999 | | | V |

### Number of semester: 3

| Code | Name of the course / Name of the group of courses<br>*(in case of groups of courses the list of codes of their members)*<br>*Tutors, **authors** and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| B3MPROJ8 | **Project**<br>*Tomáš Drábek, Martin Hlinovský, Petr Pošík, Drahomíra Hejtmanová, Jaroslava Matějková, Tomáš Svoboda, Martin Šipoš, Jana Zichová* | Z | 8 | 0p+6s | Z | P |
| B3M38MSE | **Modern Sensors**<br>*Antonín Platil, Michal Janošek **Antonín Platil** Antonín Platil (Gar.)* | Z,ZK | 6 | 2P+2L | Z | PO |
| B3M38SPD | **Data Acquisition and Transfer**<br>***Radislav Šmíd*** | Z,ZK | 6 | 2P+2L | Z | PO |
| 2015_MKYRPV2 | **Povinně volitelné předměty programu**<br>*B3M35DRS,B3M38INA,..... (see the list of groups below)* | Min. cours.<br>1 | Min/Max<br>6/90 | | | PV |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Max. cours. 15 | | | | |
| 2015_MKYRVOL | **Volitelné odborné předměty** | Min. cours. 0 | Min/Max 0/999 | | | V |

Number of semester: 4

| Code | **Name of the course / Name of the group of courses** ***(in case of groups of courses the list of codes of their members)*** *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| BDIP30 | **Diploma Thesis** | Z | 30 | 22s | L | P |

## List of groups of courses of this pass with the complete content of members of individual groups

| Kód | Name of the group of courses and codes of members of this group (for specification see here or below the list of courses) | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| **2015_MKYRPV2** | **Povinně volitelné předměty programu** | **Min. cours. 1 Max. cours. 15** | **Min/Max** 6/90 | | | **PV** |

| | | | | | |
|---|---|---|---|---|---|
| B3M35DRS | Dynamics and Control Networks | B3M38INA | Integrated Avionics | B3M37KIN | Space Engineering |
| B3M37LRS | Aeronautical radio systems | B3M33MKR | Mobile and Collective Robotics | B3M35NES | Nonlinear Systems and Chaos |
| B3M35OFD | Estimation, filtering and detect ... | B3M35ORR | Optimal and robust control | B3M33PRO | Advanced robotics |
| B3M35PSR | Real -Time Systems Programming | B3M33PIS | Industrial Information Systems | B3M38PSL | Aircraft Avionics |
| B3M35SDU | Discrete Event Systems | B3M35SRL | Flight Control Systems | B3M33UI | Artificial Intelligence |

| | | | | | | |
|---|---|---|---|---|---|---|
| **2015_MKYRVOL** | **Volitelné odborné předměty** | **Min. cours. 0** | **Min/Max** 0/999 | | | **V** |

## List of courses of this pass:

| Code | Name of the course | Completion | Credits |
|---|---|---|---|
| B3M33ARO | Autonomous Robotics | Z,ZK | 7 |
| The Autonomous robotics course will explain the principles needed to develop algorithms for intelligent mobile robots such as algorithms for: (1) Mapping and localization (SLAM) sensors calibration (lidar or camera). (2) Planning the path in the existing map or planning the exploration in a partially unknown map and performing the plan in the world. IMPORTANT: It is assumed that students of this course have a working knowledge of optimization (Gauss-Newton method, Levenberg Marquardt method, full Newton method), mathematical analysis (gradient, Jacobian, Hessian), linear algebra (least-squares method), probability theory (multivariate gaussian probability), statistics (maximum likelihood and maximum aposteriori estimate), python programming and machine learning algorithms. | | | |
| B3M33MKR | Mobile and Collective Robotics | Z,ZK | 6 |
| The course introduces a basic mobile robot structure design together with control methods aimed to achieve autonomous and collective behaviors for robots. Methods and tool s for data acquisition and processing are presented herein with the overall goal to resolve the task of autonomous navigation for mobile robots comprising the tasks of sensor fusion, environmental modeling including Simultaneous Localization And Mapping (SLAM) approaches. Besides sensor-processing related tasks, methods for robot trajectory planning will be introduced. The central topic of the course stands in specific usage of the afore methods capable of execution with groups of robots and taking the advantage of their cooperation and coordination in groups. Labs and seminars are organized in a form of an Open Laboratory whereas the students will implement some fundamental algorithms and study their properties on real data. | | | |
| B3M33PIS | Industrial Information Systems | Z,ZK | 6 |
| The aim of this course is to provide students with the necessary set of skills essential for the design and management of modern production systems. In the first part of the course, the students will learn about methods of modeling and simulation of discrete production systems. Students will then gain insight into methods for data analysis to optimize the production as well as into methods for process mining. The final part of the course deals with methods of data and knowledge modeling, which are necessary for explicit capture and machine utilization of information and knowledge about production. | | | |
| B3M33PRO | Advanced robotics | Z,ZK | 6 |
| We will explain and demonstrate techniques for modelling, analyzing and identifying robot kinematics. We will explain more advanced principles of the representation of motion in space and the robot descriptions suitable for identification of kinematic parameters from measured data. We will explain how to solve the inverse kinematic task of 6DOF serial manipulators and how it can be used to identify its kinematic parameters. Theory will be demonstrated on simulated tasks and verified on a real industrial robot. | | | |
| B3M33UI | Artificial Intelligence | Z,ZK | 6 |
| The course deepens and enriches knowledge of AI gained in the bachelor course Cybernetics and Artificial Intelligence. Students will get an overview of other methods used in AI, and will get a hands-on experience with some of them. They will master other required abilities to build intelligent agents. By applying new models, they will reiterate the basic principles of machine learning, techniques to evaluate models, and methods for overfitting prevention. They will learn about planning and scheduling tasks, and about methods used to solve them. | | | |

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<tr><td colspan="4">Student will also get ackquainted with the basics of probabilistic graphical models, Bayesian networks and Markov models, and will learn their applications. Part of the course will introduce students to the area of again populat neural networks, with an emphasis to new methods for deep learning.</td></tr>
<tr><td>B3M35DRS</td><td>Dynamics and Control Networks</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">This course responds to an ever-increasing demand for understanding contemporary networks – large-scale complex systems composed of many components and subsystems interconnected into a single distributed entity. Herein, we will consider fundamental similarities between diverse areas such as e.g. forecasting the spread of global pandemics, public opinion dynamics and manipulation of communities through social media, formation controls for unmanned vehicles, energy generation and distribution in power grids, etc. Understanding such compelling issues goes far beyond the boundaries of any single physical, technological or scientific domain. Therefore, we will analyze phenomena across different domains, involving societal, economic and biological networks. For such networked systems, the resulting behavior depends not only on the characteristics of their individual components and details of their physical or logical interactions, but also on a precise way those components are interconnected – the detailed interconnection topology. For that reason, the first part of the course introduces fundamental theoretical and abstract computational network analysis concepts; in particular, the algebraic graph theory, network measures and metrics and fundamental network algorithms. The second part of the course subsequently views networks as dynamical systems, studies their properties and ways in which these are controlled, using mainly methods of automatic control theory.</td></tr>
<tr><td>B3M35LSY</td><td>Linear Systems</td><td>Z,ZK</td><td>8</td></tr>
<tr><td colspan="4">The purpose of this course is to introduce mathematical tools for the description, analysis, and partly also synthesis, of dynamical systems. The focus will be on linear time-invariant multi-input multi-output systems and their properties such as stability, controllability, observability and state realization. State feedback, state estimation, and the design of stabilizing controllers will be explained in detail. Partially covered will be also time-varying and nonlinear systems. Some of the tools introduced in this course are readily applicable to engineering problems such as the analysis of controllability and observability in the design of flexible space structures, the design of state feedback in aircraft control, and the estimation of state variables. The main motivation, however, is to pave the way for the advanced courses of the study program. The prerequsites for this course include undergraduate level linear algebra, differential equations, and Laplace and z transforms.</td></tr>
<tr><td>B3M35NES</td><td>Nonlinear Systems and Chaos</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The goal of this course is to introduce basics of the modern approaches to the theory and applications of nonlinear control. Fundamental difference when dealing with nonlinear systems control compared with linear case is that the state space approach prevails. Indeed, the frequency response approach is almost useless in nonlinear control. State space models are based mainly on ordinary differential equations, therefore, an introduction to solving these equations is part of the course. More importantly, the qualitative methods for ordinary differential equations will be presented, among them Lyapunov stability theory is crucial. More specifically, the focus will be on Lyapunov function method enabling to analyse stability of nonlinear systems, not only that of linear ones. Furthemore, stabilization desing methods will be studied in detail, among them the so-called control Lyapunov function concept and related backstepping method. Special stress will be, nevertheless, given by this course to introduce and study methods how to transform complex nonlinear models to simpler forms where more standard linear methods would be applicable. Such an approach is usually refered to as the so-called exact nonlinearity compensation. Contrary to the well-known approximate linearization this method does not ignore nonlinearities but compensates them up to the best possible extent. The course introduces some interesting case studies as well, e.g. the planar vertical take off and landing plane ("planar VTOL"), or a simple 2-dimensional model of the walking robot.</td></tr>
<tr><td>B3M35OFD</td><td>Estimation, filtering and detection</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">This course will cover description of the uncertainty of hidden variables (parameters and state of a dynamic system) using the probability language and methods for their estimation. Based on bayesian problem formulation principles of rational behavior under uncertainty will be analyzed and used to develop algorithms for parameter estimations (ARX models, Gaussian process regression), filtering (Kalman filter) and detection (likelihood ratio theory) . We will demonstrate numerically robust implementation of the algorithms applicable in real life problems for the areas of industrial process control, robotics and avionics.</td></tr>
<tr><td>B3M35ORR</td><td>Optimal and robust control</td><td>Z,ZK</td><td>6</td></tr>
<tr><td>B3M35PSR</td><td>Real -Time Systems Programming</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The goal of this course is to provide students with basic knowledge about software development for real-time systems, for example in control and embedded applications. The focus is on embedded systems equipped with a real-time operating system (RTOS). Lectures will cover real-time systems theory, which can be used to formally verify timing correctness of such systems. Another set of lectures will introduce methods and techniques used for development of safety-critical systems, whose failure may have catastrophic consequences. During labs, students will first solve a few simple tasks to familiarize themselves with basic components of VxWorks RTOS and to benchmark the used OS and hardware (Xilinx Zynq). The obtained metrics represent the typical criteria for assessing the suitability of a given platform for the given application. After the simple tasks, students will solve a complex task of time-critical motion control application which will require full utilization of RTOS features. All the tasks at the labs will be implemented in C (or C++) language.</td></tr>
<tr><td>B3M35SDU</td><td>Discrete Event Systems</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Discrete event systems (DES) will be defined formally regarding their description and modelling. Students will learn to understand and use several ways of DES modelling and verification. The acquired knowledge will be evaluated at real (in most cases) industrial applications.</td></tr>
<tr><td>B3M35SRL</td><td>Flight Control Systems</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course is devoted to classical and modern control design techniques for autopilots and flight control systems. Particular levels are discussed, starting with the dampers attitude angle stabilizers, to guidance and navigation systems. Next to the design itself, important aspects of aircraft modelling, both as a rigid body and considering flexibility of the structure, are discussed.</td></tr>
<tr><td>B3M37KIN</td><td>Space Engineering</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The subject acquaints students with the basics of physics of the space environment and the technologies used in space systems, satellites, spacecrafts and launchers and methods used for the design and preparation of space missions. Subject matter includes a detailed description of the instrumentation of satellites and spacecrafts and its resistance to external influences of the space environment, and analysis of instruments and systems for spacecratfts and methods of their testing. It provides a basic overview of the trajectories of spacecrafts and their applications. The course also covers optoelectronics in space systems, sensors used, their modeling and description. It discusses the principles of underlying calculations, simulations and their processing.</td></tr>
<tr><td>B3M37LRS</td><td>Aeronautical radio systems</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course introduces students to the aeronautical radio engineering, aeronautical analogue, digital and satellite communication systems, aeronautical radio navigation including satellites navigation, primary secondary and passive radiolocation. The course gets students theoretical and practical knowledge of the operation of the aeronautical radio systems and their integration to the aircraft systems.</td></tr>
<tr><td>B3M38DIT</td><td>Diagnostics and Testing</td><td>Z,ZK</td><td>7</td></tr>
<tr><td>B3M38INA</td><td>Integrated Avionics</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course Integrated Modular Avionics (IMA) focuses on a modern concept of the approach to the development and design of aircraft electronics (avionics), where the transition from distributed HW systems to SW blocks. They use high-speed connections to exchange data in applications related to paid air transport. The existing regulatory basis and airspace sharing define the requirements for the accuracy, reliability, and functionality of electronic systems even in the event of a failure. In the course, students will learn details about the requirements for so-called safety-critical multi-sensor systems, methods of data processing from predetermined systems, fault detection methods, selection of primary computer and control system in parallel architectures, bus technology, and methods of testing/certification of aircraft instruments.</td></tr>
<tr><td>B3M38MSE</td><td>Modern Sensors</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">An overview of sensors of physical quantities used in industry and in research and methods of signal processing.</td></tr>
<tr><td>B3M38PSL</td><td>Aircraft Avionics</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The subject is focused into a field of aircraft avionics including principles, sensors, measurement and evaluation systems and signal/data processing methods. The subject goes into details of studied systems, i.e. engine and aircraft monitoring systems, power systems, pressure-based systems, low-frequency navigation means, and flight recorders. The subject introduces currently used technology and methodology on aircraft and thus serves to understand fundamentals of avionics. Inertial navigation systems are discussed in more details as well as their aiding systems and sensors. The course focuses on both small and large aircraft as well as on UAV suited avionics.</td></tr>
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<tr><td>B3M38SPD</td><td>Data Acquisition and Transfer</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The aim of the course is to acquaint students with principles and limits of data transmission from sensors and similar sources of information for IoT and M2M, wireless sensor networks and specific algorithms, respecting the limiting conditions of their function. The basic algorithms of distributed information processing in sensor networks, as well as technology for energy harvesting for powering the wireless nodes of the network, will be studied.</td></tr>
<tr><td>B3M38VBM</td><td>Videometry and Contactless Measurement</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">This course focuses on CCD and CMOS video sensors, and optoelectronic sensors in general and their use in contactless videometric measurement systems. Further optical radiation, its features, behavior and its use for acquiring object parameters, optical projection system, design of measurement cameras and processing of their signal will be presented. Students will design, realize and debug an independent project - 'Optoelectronic reflective sensor', during labs.</td></tr>
<tr><td>B3M38VIN</td><td>Virtual Instrumentation</td><td>Z,ZK</td><td>6</td></tr>
<tr><td>B3M38ZDS</td><td>Analog Signal Processing and Digitalization</td><td>Z,ZK</td><td>6</td></tr>
<tr><td>B3MPROJ8</td><td>Project</td><td>Z</td><td>8</td></tr>
<tr><td>B3MPVT</td><td></td><td>KZ</td><td>6</td></tr>
<tr><td colspan="4">Teamwork is the basis of most of the activities that people perform in companies and their personal lives. In this course, students can try how to solve a technical task in a team, how to cooperate, how to communicate together and how to solve problems such as project delays, how to include external influences in the plan, etc.</td></tr>
<tr><td>BDIP30</td><td>Diploma Thesis</td><td>Z</td><td>30</td></tr>
<tr><td colspan="4">Independent final comprehensive work for the Master's degree study programme. A student will choose a topic from a range of topics related to his or her branch of study, which will be specified by branch department or branch departments. The diploma thesis will be defended in front of the board of examiners for the comprehensive final examination.</td></tr>
<tr><td>BEZM</td><td>Safety in Electrical Engineering for a master´s degree</td><td>Z</td><td>0</td></tr>
<tr><td colspan="4">The course provides for students of all programs periodic training guidelines for health and occupational safety and gives knowledge of electrical hazard of given branch of study. Students receive indispensable qualification according to the current Directive of the Dean.</td></tr>
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For updated information see http://bilakniha.cvut.cz/en/f3.html
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