

Signals, Instruments, and Systems

Summer Semester 2025-2026

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Course Website: https://disal.epfl.ch/teaching/signals_instruments_systems/

1 Credits and Workload

Signals, Instruments, and Systems (SIS) distributes 5 ECTS. According to the European Commission guidelines, 1 ECTS is equivalent to up to 30h of workload. Therefore, the total workload for SIS will be about 150h over the whole semester. The approximate breakdown of the workload is 60h for lecture attendance and exam preparation, 35h for exercises (labs and self-assessment test, preparation time included), and 55h for carrying out and producing requested deliverables for the course project.

2 Grade

The final grade for SIS will take into account the performance in the final written exam as well as *individual* and *team* contribution in the context of the course project. Exercises are ungraded but solving them in a thorough way will help the students to be well-prepared for course project, as well as for the final exam. 50% of the grade will be acquired during the semester, based on the performances in the course project. The final written exam will last 180 minutes and will involve questions focusing on the different topics covered during the course and the exercises. 50% of the grade will be based on the performance during the final written exam.

3 Reading

Being a pioneering course in the curriculum of environmental engineers, SIS does not have a course book. The lecture notes are the reference for the course. *Preliminary* lecture notes will be available on the Moodle server *shortly before* a given lecture (Sunday evening usually), in PDF format. *Definitive* lecture notes will be available *after a given lecture* in timely fashion on both the Moodle server and the web pages of the course.

Additionally, complementary reading material will be made available, if appropriate, in electronic format on the Moodle server. Access to this material will be limited to people enrolled in the class and controlled via username and password. Most of this material is copyrighted and therefore it should be exclusively used for course purposes. Further reading pointers are suggested in the last slide of each lecture.

4 Lecture

Lecture will be given primarily with the help of an LCD projector. The lectures will be offered exclusively on-site. Lectures will *not* be recorded this year but video material about lectures of a previous edition will be made available to students. While this edition of the

course will be roughly aligned with the previous one, changes are possible. Finally, we consider the exercise of following, interacting, and at least partially understanding in real-time a lecture, one of the fundamental skills to be acquired for future professional activities. We therefore strongly encourage students to attend the lecture of this year *in a regular way*.

5 Laboratories

The course will involve a total of nine lab exercises lasting three hours as well as a programming self-assessment test. The self-assessment test will focus on the verification of the Matlab and C programming pre-requisites that are necessary for the course and should have been acquired in previous courses. It will take place in the first week of the course. The test is ungraded but will mention points so that students can estimate their preparation in terms of programming. Students are expected to submit their obtained score in an anonymous fashion, via the Moodle server.

All the lab exercises will be also ungraded, without points mentioned on the assignment. The exercises have been designed and tested such as they are doable in the GR computer rooms, leveraging a Linux operating system. While we strongly recommend students to carry out their exercises in the available computer rooms, most of the exercises can be also carried out on personal machines, provided that the corresponding software packages have been downloaded and correctly installed on the specific operating systems (not necessarily Linux). While we will make available some instructions on the Moodle server for this purpose, as the current teaching conditions allow any student to attend on-site exercises, we will not offer any assistance for the deployment of such tools on private machines.

The assignments of the exercises will be made available at latest by Wednesday (mid-day) before a given lab session via the Moodle server, in PDF format. At the beginning of each lab session, a mini-tutorial of typically 5-10 minutes will be given by a teaching assistant. The corresponding slides will be made available on the Moodle server after the lab session. Official solutions will be distributed for the programming self-assessment test and each exercise, after a given laboratory session. For the exercises, we encourage the students to take their own personal notes (they will be useful for all the graded assignments, namely the course project and the final exam).

Further discussion on specific points of the exercises can happen during office hours. Office hours will have to be scheduled upon appointment via the TA mailing list and the Moodle discussion forum will also be leveraged for exercise discussion, but only for topics of common interest.

6 Course Project

The acquisition of the laboratory content will be verified through a comprehensive graded assignment involving an individual and a team contribution: a course project (55 h effort for each student, carried out by a team of *three* students by default, *two* in exceptional cases, in case the total number of students is not divisible by three). The course project effort includes reading the distributed material, implementing, reporting, and demonstrating the obtained solution.

The project assignment will be made available before the lab session of the Week 8 and will be concluded at the end of Week 14. During Week 11 and 13 (Week 12 not offering any lab session because of Ascension) there will be no dedicated exercises but the lab sessions will offer assistance for the course project. The course project will also involve a demonstration of the implemented solution on one of the machines of the GR computer rooms (logistically it will happen in another room instrumented with the very same type of machine and operating system). The demonstration will happen in the last week of the semester; an exact schedule of all steps associated to the course project will be communicated in timely fashion.

No further assistance outside the specific lab sessions mentioned above will be dedicated to the course project.

7 Course Syllabus

WEEK 1 – February 16 and 19

Lecture – AM

Organization of the course (team, workload, credits); overview of the course content; introduction to signal processing – signals, time continuity and time discretization, analog and digital signals, baseline concepts.

Reading

Lecture notes.

Lab

Self-assessment test for Matlab and C programming.

WEEK 2 – February 23 and February 26

Lecture

Introduction to signal processing – Fourier series and transform, convolution.

Reading

Lecture notes.

Lab 1

Exercise in Matlab on signal processing concepts explained in the lecture.

WEEK 3 – March 2 and 5

Lecture

Introduction to signal processing – sampling, reconstruction, and aliasing.

Reading

Lecture notes.

Lab 2

Exercise in Matlab on signal processing concepts explained in the lecture.

WEEK 4 – March 9 and 12

Lecture

Introduction to signal processing – the Laplace transform for continuous-time signals and systems; frequency response, impulse response and transfer function; analog filter analysis and synthesis.

Reading

Lecture notes.

Lab 3

Exercise in Matlab on signal processing concepts explained in the lecture.

WEEK 5 – March 16 and 19**Lecture**

Introduction to signal processing – Bode plots; the Z-Transform for discrete-time signals and systems; filter order and type; digital filter analysis and synthesis.

Reading

Lecture notes.

Lab 4

Exercise in Matlab on signal processing concepts explained in the lecture.

WEEK 6 – March 23 and 26**Lecture**

Introduction to embedded systems – terminology, main modules (perception, communication, computation, and action); sensor types and performance, power consumption, management, generation, and storage.

Reading

- Lecture notes.
- Siegwart R. and Nourbakhsh I. R., “Introduction to Autonomous Mobile Robots”, MIT Press, 2004, Ch. 4 (pp. 89-98).

Lab 5

An introduction to embedded systems programming leveraging the DISAL Arduino node (programming in C/Python/Matlab as appropriate).

WEEK 7 – March 30 and April 2**Lecture**

Introduction to embedded systems – communication and computation; real-time programming.

Reading

Lecture notes

Lab 6

Advanced embedded system programming notions leveraging the DISAL Arduino node (programming in C/Python/Matlab as appropriate).

WEEK 8 – April 13 and 16**Lecture**

Introduction to mobile robotics – high-fidelity simulation (Webots simulator); simple control architectures and positioning systems.

Reading

- Lecture notes
- Mondada F., Bonani M., Raemy X., Pugh J., Cianci C., Klapotocz A., Magnenat S., Zufferey J.-C., Floreano D., Martinoli A., “The e-puck, a Robot Designed for Education in Engineering”. *Proc. of the 9th Conference on Autonomous Robot Systems and Competitions*, May 2009, Castelo Branco, Portugal, Vol.1, pp. 59-65.
- Michel O., “Webots: Professional Mobile Robot Simulation”. *Int. J. of Advanced Robotic Systems*, **1**: 39-42, 2004.

Lab 7

Introductory Webots lab; programming in C but use of Matlab/Python when appropriate. Project kick-off in the last hour.

WEEK 9 – April 20 and 23**Lecture**

Introduction to mobile robotics - localization through positioning systems and odometry.

Reading

- Lecture notes
- Siegwart R. and Nourbakhsh I. R., “Introduction to Autonomous Mobile Robots”, MIT Press, 2004, Ch. 3 (pp. 47-53), Ch. 4 (pp. 145-151), and Ch. 5 (185-191).

Lab 8

Positioning systems and odometry lab in Webots; programming in C but use of Matlab/Python when appropriate.

WEEK 10 – April 27 and 30**Lecture – start at 9h15**

Introduction to mobile robotics – Localization with odometry augmented with exteroceptive sensing; Kalman filtering.

Reading

- Lecture notes
- Maybeck P. S. “Stochastic Models, Estimation, and Control”, Academic Press, 1979, Ch. 1 (pp.1-16).
- Siegwart R. and Nourbakhsh I. R., “Introduction to Autonomous Mobile Robots”, MIT Press, 2004, Ch. 4 (pp. 151-154), Ch. 5 (pp. 227-233).
- Thrun S., Burgard W., and Fox D., “Probabilistic Robotics”, MIT Press, preprint, 2002, Ch. 3 (pp. 33-39).

Lab 9

Odometry augmented with exteroceptive sensing + Kalman filtering lab in Webots; programming in C but use of Matlab/Python when appropriate.

WEEK 11 – May 4 and 7**Lecture**

Environmental sensing systems - robotic localization in practice and sensor networks.

Reading

- Lecture notes.
- Siegwart R. and Nourbakhsh I. R., “Introduction to Autonomous Mobile Robots”, MIT Press, 2004, Ch. 5 (pp. 181-184 and 233-244).
- Thrun S., Burgard W., and Fox D., “Probabilistic Robotics”, MIT Press, preprint, 2002, Ch. 3 (pp. 48-51 and 62-65).
- Barrenetxea G., Ingelrest F., Schaefer G. and Vetterli M., “The Hitchhiker's Guide to Successful Wireless Sensor Network Deployments”. *Proc. of the 6th ACM Conference on Embedded Networked Sensor Systems*, November 2008, Raleigh, NC, USA, pp. 43-56.

Lab

Assistance for course project.

WEEK 12 – May 11**Lecture**

Mobile sensing systems for environmental monitoring.

Reading

- Lecture notes
- Arfire A., Marjovi A., and Martinoli A., “Enhancing Measurement Quality through Active Sampling in Mobile Air Quality Monitoring Sensor Network,” *Proc. of the IEEE Int. Conf. on Advanced Intelligent Mechatronics*, July 2016, Banff, Canada, pp. 1022-1027.
- Arfire A., Marjovi A., and Martinoli A., “Mitigating Slow Dynamics of Low-Cost Chemical Sensors for Mobile Air Quality Monitoring Sensor Networks,” *Proc. of the Int. Conf. on Embedded Wireless Systems and Networks*, February 2016, Graz, Austria, pp. 159-167.
- Marjovi A., Arfire A., and Martinoli A., “Extending Urban Air Quality Maps Beyond the Coverage of a Mobile Sensor Network: Data Sources, Methods, and Performance Evaluation”. *Proc. of the International Conference on Embedded Wireless Systems and Networks*, February 2017, Uppsala, Sweden pp. 12-23.

Lab

No lab (Ascension).

WEEK 13 – May 18 and 21**Lecture**

Robotic sensing systems for environmental monitoring and course take home messages.

Reading

- Lecture notes.
- Lochmatter T. and Martinoli A., “Tracking an Odor Plume in a Laminar Wind Field with Bio-Inspired Algorithms”. *Proc. of the Eleventh Int. Symp. Experimental Robotics*, July 2008, Athens, Greece, Springer Tracts in Advanced Robotics (2008), Vol. 54, pp. 473-482, 2008.
- Rahbar F., Marjovi A., Kibleur P., and Martinoli A., “A 3-D Bio-inspired Odor Source Localization and its Validation in Realistic Environmental Conditions,” *Proc. of the IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, September 2017, Vancouver, Canada, pp. 3983-3989.

- Ercolani C. and Martinoli A., “3D Odor Source Localization using a Micro Aerial Vehicle: System Design and Performance Evaluation”, *Proc. of the IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, October 2020, Las Vegas, NV, USA, online organization, pp. 6194-6200.
- Quraishi A., Bahr A., Schill F., and Martinoli A., “Autonomous Feature Tracing and Adaptive Sampling in Real-World Underwater Environments,” *Proc. IEEE Int. Conf. on Robotics and Automation*, May 2018, Brisbane, Australia, pp. 5699-5704.

Lab

Assistance for course project.

WEEK 14 – May 28**Lecture**

No lecture because of Pentecôte.

Reading

None

Lab

None because presentation course project.

Course project

Submission of course project deliverables by Mon 25, demonstrations on May 28.