EQ2300 Digital Signal Processing (7.5 hp)

Quick Facts

Presented: in period 2, 2020.

Language of instruction: English

Prerequisites:

- EQ1110 & EQ1120 Signals and Systems
- EQ1220/EQ1240 Signal Theory

Followup courses:

- EQ2401 Adaptive Signal Processing
- EQ2443/EQ2444/EQ2445 Project Courses

Web page: `https://kth.instructure.com/courses/11292`

Course responsible and lecturer:
Joakim Jaldén, `jalden@kth.se`, Malvinas väg 10, floor 4, 08-790 77 88.

Course Assistants:

Hamid Ghourchian, `hamidgh@kth.se`, Malvinas väg 10, floor 4

Xuechun Xu, `chunx@kth.se`, Malvinas väg 10, floor 7

Why Take the Course?

Digital systems provide larger flexibility and better accuracy at a lower cost, compared to analogue systems. For this reason, they are used in most technical areas, including telecommunications, automatic control, audio, image processing, medical and military applications. The course provides a solid background in digital signal processing that is crucial to many such applications.

Expectations on the Student when the Course Starts

At the beginning of the course, each student is expected to:

- Know how to describe and analyze discrete-time signals and linear systems, both in the time and in the frequency domain, using the Discrete Time Fourier transform and the z-transform.
- Be able to describe and analyze discrete-time stationary stochastic signals, in terms of their autocorrelation sequence and spectral density, and to determine how these properties are affected by linear filtering.
- Know how to perform sampling and reconstruction of continuous-time signals and describe how these operations affect both deterministic and stochastic signals, both in the time and frequency domains.
- Have a good level of linear matrix and vector algebra.

Expectations on Students Having Finished the Course

After the course, each student is expected to be able to:

- Give examples of signal processing problems that can be solved using digital signal processing.
- Implement digital signal processing methods based on a given algorithmic description or theory.
- Show insight into the underlying principles of the FFT algorithm, use this algorithm to filter digital signals in the frequency domain, and calculate its complexity.
- Explain and give examples of how digital filters can be implemented in software and hardware, and show insight into the positive and negative aspects of different implementations.
- Approximate filters with a given impulse responses and transfer function using FIR filters, and to quantitatively and qualitatively assess that approximation.
- Show insight into what happens when a filter is implemented on a fixed point processor, be able to model and calculate quantization and fixed point noise, and based on the calculations choose between implementations.
- Estimate the power spectral density (PSD) of a time-discrete stochastic process using non-parametric and parametric methods and show some insight into the positive and negative aspects of the different approaches.
- Formulate and implement MMSE-optimal FIR filters for a given signal model.
- Implement and use methods to increase and decrease the sample rate of a signal and explain, quantitatively and qualitatively, how the signal is affected in the time and frequency domains.
- Implement and use a filter-bank to split a signal into sub-bands and then reconstruct the original signal.
- Combine the methods and results described above to solve simple signal processing tasks, and be able to report and motivate the chosen solution in the form of a written technical report.

A student that is approved with a higher grade (than E) should also be able to:

- Combine the methods above to solve complex signal processing problems.
- Provide convincing and technically accurate motivations for solutions and methods chosen, as for example for a chosen spectrum estimator.
- Show deep insight into the theoretical results of the course.

Sources of Information

All course information is available at the web page in Canvas, which will be continuously updated during the course.

Compulsory Course Activities

Project Assignments (1.0 hp, "PRO1")

A compulsory project assignments is included in the course. The task of the project is to design a digital FIR filter, and you will reuse the filter that you designed during the laboratory exercise. The project should be documented in a short written technical report. You are encouraged to work in groups. However, each report should have a maximum of two authors. All material needed for the project will have been covered in lectures by November 13. The deadline for handing in the project report is **Sunday November 29, 2020.**

Laboratory Exercise (0.5 hp, "LAB1")

The course includes one hands-on lab, where you will have to test DSP code on a hardware platform. New since 2017 is that the hardware platform will switch form a dedicated DSP development platform, to an Arduino based platform. Instructions for the lab is available on the course web-page. The lab will be conducted during the period **December 8 to 11, 2020**.

Exam, (6.0 hp, "TEN1" in Ladok)

The written exam (pending approval by vice rector of education) consists of 5 question with a maximum of 10 points each. 24 points will be sufficient for a passing grade.

The following items may be used during the exam:

- Collection of Formulas in Signal Processing (pink pamphlet).
- One A4 of your own notes. You may write on both sides, and it does not have to be hand written but cannot contain full solutions to tutorial problems or previous exam problems.
- Summary notes for EQ2300.
- An unprogrammed pocket calculator.
- BETA Mathematics Handbook. If you want to use some other collection of mathematical tables and formulas, check with the course responsible before the exam.

Note that the list of allowed items **does not include** the course book. This is mainly due to the observation that many students obtain one of the books in a purely electronic form that cannot be allowed in the exam, or do not obtain any book at all in some cases. All critical formulas of the course are included in the summary notes, which can be used during the exam.

Registration for the exam should be done through the personal pages at `www.kth.se`. Please take note of the exam rules at KTH available at `https://www.kth.se/en/student/kurs/tentamen`. According to KTH rules, students who fail on the exam but are "close to" passing it, will receive the temporary grade Fx, i.e. a chance to do an extra assignment which can lead to grade E. The students who obtain grade Fx will receive a personal email with further instructions after the grading.

Other Scheduled Activities

Lectures

The 12 lectures are intended to provide an overview of the material and show some examples of applications. Each lecture is followed by a tutorial session on the topic of that lecture. The lectures will for 2020 be held in zoom, while the tutorials take place on campus.

Lectures 2-11 will be so called flipped-classroom lectures and build on online video material available from the course web and hosted on YouTube. During the zoom session it will be assumed that students are familiar with the preparatory video material. No recap of this material will be provided during the zoom session. Instead, the time will be primarily focussed on group work centered around concept based questions.

Tutorials

The 12 tutorials will be given in two parallel groups. The recommended problems for the tutorials are contained in the binder named tutorials.

Literature

- The video lectures along with the summary notes covers all the course content at a basic level. This said, in order to obtain a deeper understanding of the course material it is recommended that you also obtain a textbook that coves the subject area. Reading instructions are available on the web for the following recommended textbooks:
  - J.G. Proakis & D.G. Manolakis, Digital Signal Processing: Principles, Algorithms and Applications, 4th ed., Pearson Education Inc. 2006, ISBN: 0-13-187374-1.
  - P.S.R. Diniz, E.A.B da Solva & S.L. Netto, Digital Signal Processing: System Analysis and Design, 2nd ed., Cambridge University Press 2010, ISBN: 978-0-521-88775-5.
  - M.H. Hayes, Statistical Digital Signal Processing and Modeling, John Wiley & Sons, Inc., ISBN: 0-47-159431-8.
- Some extra material is available through the course web. In particular, you will be interested in the following material found at the bottom of the modules page:
  - Summary notes for EQ2300
  - The collection of Tutorial Problems.
  - Collection of Formulas in Signal Processing (the pink formula collection)
- Auxiliary material, and the project and lab instructions, will be made available on the course web.