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Applied Signal Processing

Lecture 1

Tomas McKelvey
Signal Processing and Biomedical Engineering
Electrical Engineering

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Today

- Course structure
- Introduction to the subject
- Signals and systems for continuous time signal

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Course Material

All material in the course is available on

Canvas

chalmers.instructure.com

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Course Staff

- **Prof. Tomas McKelvey,** mckelvey@chalmers.se , lecturer, examiner
- **Arni Alfredsson,** arnia@chalmers.se, teaching assistant (TA)
- **Andreas Buchberger,** andreas.buchberger@chalmers.se, TA
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Structure of Course

- 15 Lectures (2 hours each)
- 4 Demonstrations (2 hours each)
- 3 Tutorials (2 hours each)
- 3 Hand-in problems
- 2 Projects (3 reports/software, 2 oral exams)

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Learning Outcomes (1)

After completing the course the student should be able to:

- in both time-domain and frequency-domain analyze the effect of sampling, linear filtering and signal reconstruction
- explain the relation between the Fourier transform, discrete Fourier transform and fast Fourier transform and apply the discrete Fourier transform to perform block based linear filtering
- apply linear filter design techniques to construct FIR and IIR filters satisfying given specifications
- derive the autocorrelation function and spectrum for signals modeled as filtered white noise

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Learning Outcomes (2)

- apply LMS, RLS and Kalman filters to linear adaptive filtering problems and do simplified analysis regarding stability and rate of convergence
- apply multi-rate techniques to signal processing problems to increase computational efficiency
- explain how quantization and finite word lengths effects the signal and algorithm quality and calculate the effect on the SNR
- discuss the effect of using a linear finite dimensional model as an approximation for an infinite dimensional linear systems.
- implement signal processing algorithms on a DSP-system

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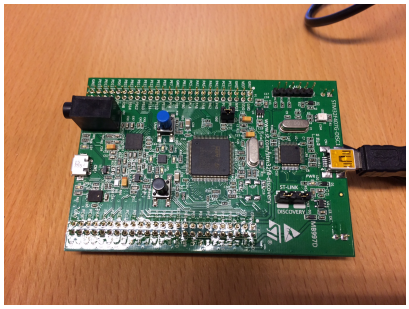
DSP hardware



- STM32F407 based experimental board
- ARM based 32-bit processor
- Mic input and stereo out audio interface
- Programmable using PlatformIO toolchain (available for Windows, Mac OS X & Linux

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Experimental kit

- DSP board in housing
- Stereo loudspeakers
- USB cable for programming
- USB cable for monitor function (attached to board)

All course participants will be provided with one kit per person (voluntary)

The kit must be returned by the end of the course at the last oral examination.

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Distribution of DSP-kits

- Thursday Nov 7
- Time: 11:30-12:30
- Room 7430 (Landahlsrummet) in EDIT building, level 7.
- Bring signed agreement (has been sent by email to you)

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Projects

- 1. Acoustic Communication System
  - 1A: Baseband Equalization using OFDM
  - 1B: Interpolation, Modulation, Demodulation and Decimation
- 2. Noise Cancellation with Adaptive Filters

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Project format

- Performed using the experimental kit and Matlab
- 2 weeks / project part
- 4 students/group
- Written report, software and oral examination

> **Start projects early**
> **Use the consultation times**

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Hand-in problems

- Individual
- 3 problems
- Due (week 3, 5 and 7)

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Written examination

- Wednesday January 15, 2020, at 14-18
- Design problems, Analysis problems, Problems which test conceptual understanding
- Old exams are available on Canvas

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Scoring System

What	Max Score
Hand-in-problems	12
Projects	36
Written Examination	52
Total	*100*

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Requirements to pass

- A total score of minimum 40
- Pass the oral project examinations
- Approved projects (score ≥ 3 per project report/software)

Grading based on total score

- 40-59 -> grade 3
- 60-79 -> grade 4
- 80-100 -> grade 5

- Note! You don't need to take the written examination (if you satisfy the three points on top)

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Academic integrity

- Hand-in problems are *individual*. This means that each student should solve the problems, write necessary computer code and report the result without *direct* help from fellow students or anyone else.
- The projects are group work. This means the group together work towards a solution and report the findings in a joint report which is *individual* for each group (see above for meaning of individual).
- When reporting solutions in writing, copying text or other material from books, Internet or from other sources (like your fellow students) without referring to the source is not a correct academic behavior.
- Students whom are suspected not to respect the rules of academic integrity will be reported to the President and risk possible disciplinary actions.

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However

- In all other learning activities which are not directly part of an examination we promote an open attitude and collaboration between all parties involved.
- Please ask questions and interact
  - It will enhance your learning of the subject

There are no stupid questions!

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Literature

- B. Mulgrew, P. Grant and J. Thompson. Digital Signal Processing - Concepts and Applications, 2nd ed. Palgrave McMillan 2003.
- E-books on Signal Processing
- Lecture notes. (Canvas)
- An introduction to the C-programing language (Canvas)
- Other material such as hand in problems, project memos and Matlab study material is/will be posted on Canvas.

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Sign up!

- On Canvas
  - Tutorial groups (1-6)
  - Project groups (4 students per group)
- Note!!
  - Exam is Wed Jan 15, 2019 at 14-18

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Introduction to the DSP-subject

DSP = Digital signal processing (the algorithms)
= Digital signal processor (type of hardware)

Signals are everywhere:

- Electric: voltages, currents, electromagnetic waves
- Acoustic: Sound waves, pressures
- Mechanical: vibrations, angular motion, velocities, forces, moments, pressures




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Sampling and Quantization

Physically based signals are *continuous* in **time, space** and **amplitude**

Sampling and quantization of the signal is required to in order to process the signals algorithmically in a computer

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The digital (r)evolution

The rapid development of low cost, low power digital circuits has enabled an enormous amount of DSP applications to emerge

Multimedia: speech-audio noise-reduction, coding, compression (MPEG-4,MP3, CD , …)

Radio, mobile phones: Modulation transmission

Radar, Sonar: filtering, target detection, tracking

Control: servo-mechanisms, plant control

Biomedical: analysis, diagnosis, monitoring, therapy, tele-medicin, e-Health

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What is a DSP system?

- Processing of signals: filtering, modulation etc.
  - Changes the signal
- Analysis of signals: transforms, model based analysis
  - Extracts features from the signal
- Detection and classification
  - Take decisions

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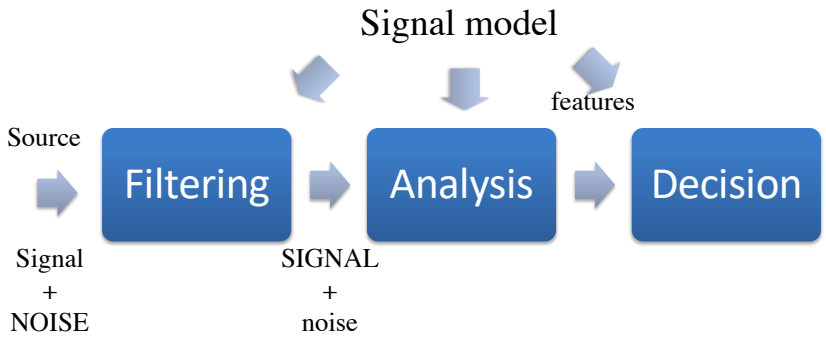
Common SP-structure



- Digital radio receiver
- Radar Systems
- Electrocardiography (ECG) analysis

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How is DSP implemented?

Basic building block is simple gate logic
— forming adders, multipliers and decision logic

Different levels implementation:

- Desktop computers with software
- Dedicated signal processors with software (embedded systems)
- Field programmable gate arrays (FPGA)
- Application specific integrated circuits (ASIC)

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Properties of DSP

- Signal is always
  - sampled (discretized in time and space)
  - and quantized (discretized levels)

  Approximate representation of the underlying continuous signal
- AD/DA converters necessary
  - Cost increases with with number of quantization levels and the sampling frequency
- Limited bandwidth
  - Clock frequency of the digital circuitry
    - Upper bound on achievable rates
    - Power consumption proportional to clock frequency

However …

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Properties of DSP (2)

- Excellent control of accuracy
  - No aging, no need of calibration etc.
- Complex algorithms possible
- Flexibility
  - Mass produced standard components
  - The software provides the functionality
- Adaptivity
  - On-line learning is straightforward

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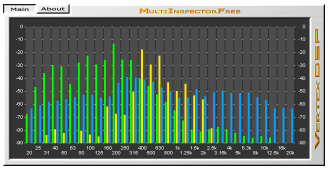
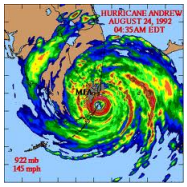
DSP is everywhere





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