

Advanced Digital Signal Processing

Part 1: Introduction

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Digital Signal Processing and System Theory



Contents of the Lecture – Part 1

- ❑ Introduction
- ❑ Digital processing of continuous-time signals
 - ❑ Sampling and sampling theorem (repetition)
 - ❑ Quantization
 - ❑ Analog-to-digital (AD) and digital-to-analog (DA) conversion
- ❑ Efficient FIR filter structures
- ❑ DFT and FFT
 - ❑ Leakage effect
 - ❑ Windowing
 - ❑ FFT structure
- ❑ Digital filters
 - ❑ FIR filters
 - ❑ IIR filters
 - ❑ Finite word-length effects



Contents of the Lecture – Part 2

- ❑ Multi-rate digital signal processing
 - ❑ Decimation and interpolation
 - ❑ Filters in sampling rate alteration systems
 - ❑ Polyphase decomposition and efficient structures
 - ❑ Digital filterbanks

Origin of this lecture

Thanks to ...

*... Prof. Dr.-Ing. Jörg Kliever
(slides are based on his script that he has written during his
time at the Christian-Albrechts-Universität zu Kiel)*



Prof. Kliewer is now with:

Klipsch School of Electrical and Computer Engineering
New Mexico State University, USA

In Addition ...

*... Dr.-Ing. Halil Özer and
Dipl.-Wirtsch.-Ing. Duc Nguyen*

helped preparing the lecture slides:



Dr. Halil Özer
CAU, DSS group



Duc Nguyen
CAU, DSS group

Literature

Books:

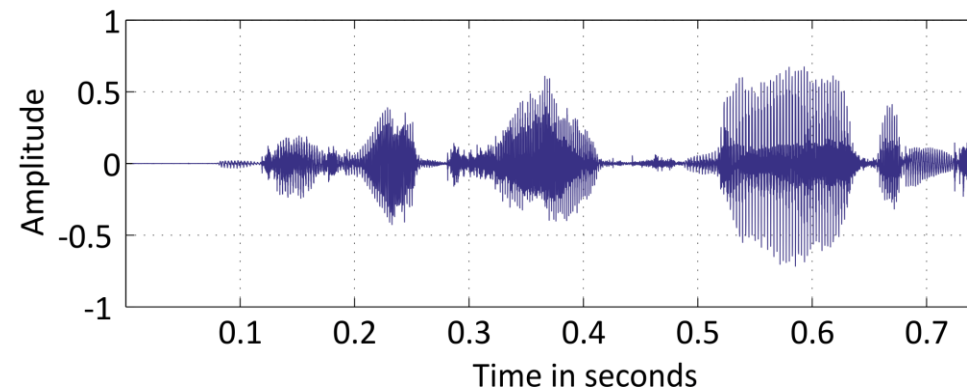
- ❑ J. G. Proakis, D. G. Manolakis: ***Digital Signal Processing: Principles, Algorithms, and Applications***, Prentice Hall, 1996, 3rd edition
- ❑ S. K. Mitra: ***Digital Signal Processing: A Computer-Based Approach***, McGraw Hill Higher Education, 2000, 2nd edition
- ❑ A. V. Oppenheim, R. W. Schaffer: ***Discrete-Time Signal Processing***, Prentice Hall, 1999, 2nd edition
- ❑ M. H. Hayes: ***Statistical Signal Processing and Modeling***, John Wiley and Sons, 1996

What does “Digital Signal Processing” mean?

The term “Signal” in “Digital Signal Processing”:

- ❑ Physical quantity that varies with time, space, or any other independent variable
- ❑ Mathematically: Function of one or more independent variables, $v(t) = 5t$, $v(n) = 20n^2$, ...
- ❑ Examples: Temperature over time $x(t)$, brightness (luminance) of an image $l(x, y)$, pressure of a sound wave over $p(x, y, z)$ or $p(x, y, z, t)$.

Speech signal:



What does “Digital Signal Processing” mean?

The term “Signal Processing” in “Digital Signal Processing”:

- ❑ Passing the signal through a system
- ❑ Examples:
 - ❑ Modification of the signal (filtering, interpolation, noise reduction, equalization, ...)
 - ❑ Prediction, transformation to another domain (e.g. Fourier transform)
 - ❑ Numerical integration and differentiation
 - ❑ Determination of mean value, correlation, probability density function, ...
- ❑ Properties of the system (e.g. linear/nonlinear) determine the properties of the whole processing operation
- ❑ The definition of a system also includes:
 - ❑ **Software** realizations of operations on a signal, which are carried out on a digital computer (software implementation of the system),
 - ❑ digital **hardware** realizations (logic circuits) configured such that they are able to perform the processing operation, or
 - ❑ most general definition: a **combination of both**.

Signals, Systems and Signal Processing – Part 3

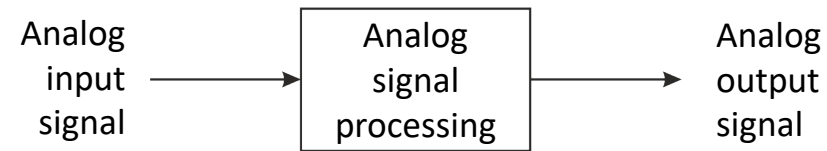
What does “Digital Signal Processing” mean?

Finally “Digital Signal Processing”:

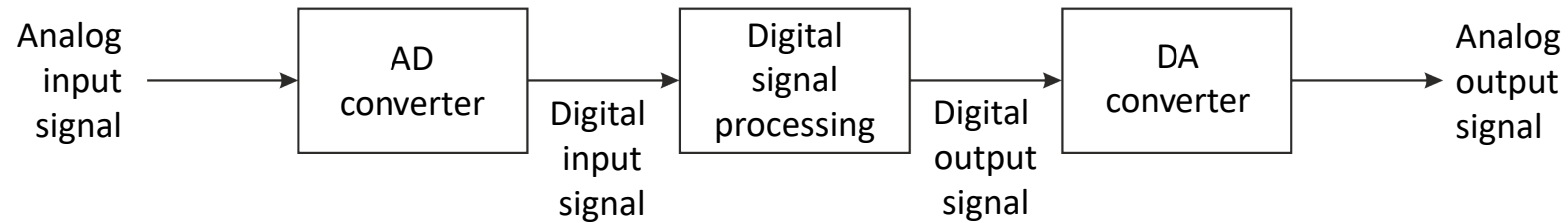
- ❑ Processing of signals by digital means (software and/or hardware)
- ❑ This includes:
 - ❑ **Conversion** from the analog to the digital domain and back (physical signals are analog)
 - ❑ Mathematical specification of the **processing operations** (Algorithm: method or set of rules for implementing the system by a program that performs the corresponding mathematical operations)
 - ❑ Emphasis on **computationally efficient algorithms**, which are fast and easily implementable.

Basic Elements of a Digital Signal Processing System

Analog signal processing:



Digital signal processing:



Why has digital signal processing become so popular?

Advantages and disadvantages of digital processing compared to analog processing:

| Property | Digital processing | Analog processing |
|----------------------------------|------------------------------------------------------------------|------------------------------------------------------------------------|
| Dynamics | Only limited by complexity | Generally limited |
| Precision | Generally unlimited (costs and complexity prop. to precision) | Generally limited (costs increase drastically with required precision) |
| Aging | Without problems | Problematic |
| Production costs | Low | Higher |
| Frequency range | Limited | Nearly unlimited |
| Linear-phase frequency responses | Exactly realizable | Approximately realizable |
| Complex algorithms | Realizable | Strong limitations |

However, digital signal processing has always also analog components (amplifiers, etc.).

Summary

- ❑ **Introduction**
 - ❑ *Contents of the lecture*
 - ❑ *Literature*
 - ❑ *Analog versus digital signal processing*
- ❑ Digital processing of continuous-time signals
- ❑ Efficient FIR filter structures
- ❑ DFT and FFT
- ❑ Digital filters
- ❑ Multi-rate digital signal processing