



Advanced Digital Signal Processing

Part 1: Introduction

Gerhard Schmidt

Christian-Albrechts-Universität zu Kiel

Faculty of Engineering

Institute of Electrical Engineering and Information Engineering

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
- ❑ 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 Kliewer
(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

Books:

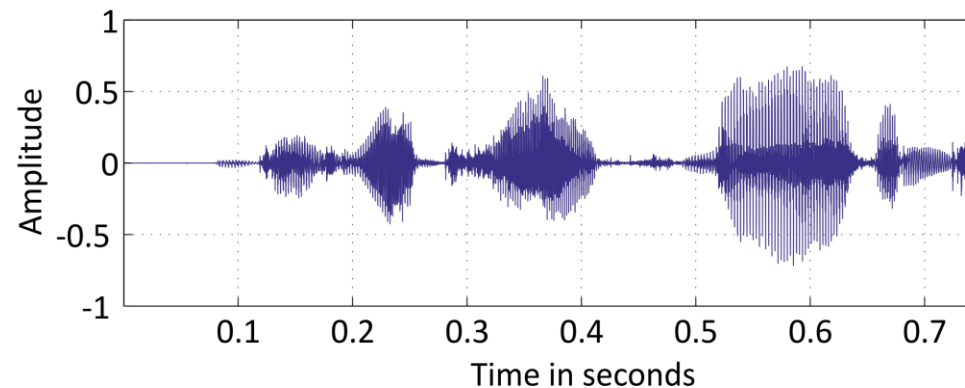
- ❑ J. G. Proakis, D. G. Manolakis: ***Digital Signal Processing: Principles, Algorithms, and Applications***, Prentice Hall, 1996, 3rd edition
- ❑ S. K. Mitra: ***Digital Signal Processing: A Computer-Based Approach***, McGraw Hill Higher Education, 2000, 2nd edition
- ❑ A. V. Oppenheim, R. W. Schaffer: ***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**.

What does “Digital Signal Processing” mean?

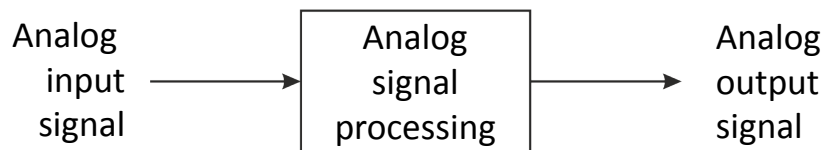
Finally “Digital Signal Processing”:

- ❑ 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.

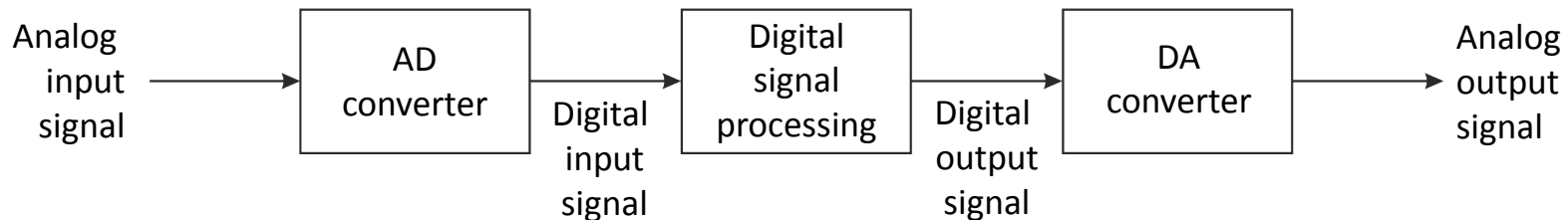
Introduction

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
- ❑ DFT and FFT
- ❑ Digital filters
- ❑ Multi-rate digital signal processing