Concept Engineering Mixed-Technology Systems

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Unsyllabus

Name	Description
Course	M 1.9 Concept Engineering Mixed-Technology Systems (CEMS)
Term	Winter 2024/25
Instructor	Prof. Dr.-Ing. M. Meiners, Dipl.-Ing. (FH) T. Ziemann

Part I.

Lecture

1. Introduction and Survey

1.1. Course Objectives

- Interfacing Microsystems
  - Mixed-technology systems (System-on-Chip, SoC)
  - System analysis
  - System specification
- Design Methodology
  - Seamlessly modeling and design over all physical domains
- PCB (System) and IC Design
  - Architecture
  - Partitioning
  - Layout

1.2. Scientific Computing

- Python (Anaconda)
- Matlab (Campus Lizenz)
- Command-line tools

1.3. EDA Tools

- PCB / System Design
  - LTspice
  - KiCad EDA
  - Altium Designer
  - SiemensEDA PCB tools
  - cadence System Design & Analysis
- IC / Silicon Design

  - IIC-OSIC-TOOLS (open-source)
  - SiemensEDA IC tools
  - cadence IC Design & Verification
  - synopsys silicon design (IC)

1.4. OS-Tools

- Microsoft-Terminal
- Microsoft-PowerShell
- MacOS-Terminal
- Linux/MacOS Shell zsh-tools,
- git (Versionskontrolle)

1.5. Code Editors

- Visual Studio Code
- Spyder IDE
- Thonny (Micro-)Python IDE
- Emacs
- Vim

1.6. Data Science

- Journaled File System
  - Directories
  - Files
- Rectangular Data
  - Comma-Separated-Values (CSV), Tab-Separated-Values (TSV)
  - csvkit: A suite of utilities for converting to and working with CSV, the king of tabular file formats.
  - [miller: Miller is like awk, sed, cut, join, and sort for name-indexed data such as CSV, TSV, and tabular JSON] (https://github.com/wireservice/csvkit)
  - Spreadsheet (.xlsx, .ods)
  - apache/iceberg: Apache Iceberg

- apache/iceberg-python: Apache PyIceberg

- Serialisation
  - Data Serialization — The Hitchhiker's Guide to Python
  - JSON
  - MessagePack: It's like JSON. but fast and small.

- Data Frames
  - Mastering Python Dictionaries: Efficient Data Storage and Retrieval - Adventures in Machine Learning
  - MAT-File Versions - MATLAB & Simulink - MathWorks Deutschland
  - HDF5 Or How I Learned To Love Data Compression And Partial I/O
  - What is Apache Parquet?
  - Feather File Format
  - pola-rs/polars: Dataframes powered by a multithreaded, vectorized query engine
  - ibis-project/ibis: Portable Python dataframe library

- Embedded Databases
  - SQL, z.B. SQlite
  - OLAP, z.B. DuckDB

1.7. Publish Computational Content

- quarto
  - Manuscripts

- Jupyter-Book

1.8. Are you writing or TeXing?

- MikTeX (Windows, MacOS, Linux)

- MacTeX (MacOS)

- TeXLive (Linux)

1.9. LaTeX Editors

- IDE's
  - TeXStudio
  - TeXMaker
- Collaborative Frameworks
  - Overleaf, Online LaTeX
  - CoCalc - Online LaTeX

1.10. Bibliography and LaTeX

- Citavi im Detail > Titel exportieren > Export nach BibTeX
- RefWorks - Library Guide Univ. Melbourne
- Benutzerdefinierte BibTex-Keys mit Zotero | nerdpause
- JabRef - Library Guide Univ. Melbourne
- EndNote - Library Guide Univ. Melbourne

1.11. Model-Based Systems Engineering (MBSE) of an Inertial Sensor System and IC Design

This winter term, the defining idea of the CEMS course is a modular board-level sensor system consisting of ADXL335 accelerometer, ADS1115 ADC and ESP8266 NodeMCU. The ADC module has to be replaced by a custom IC design.

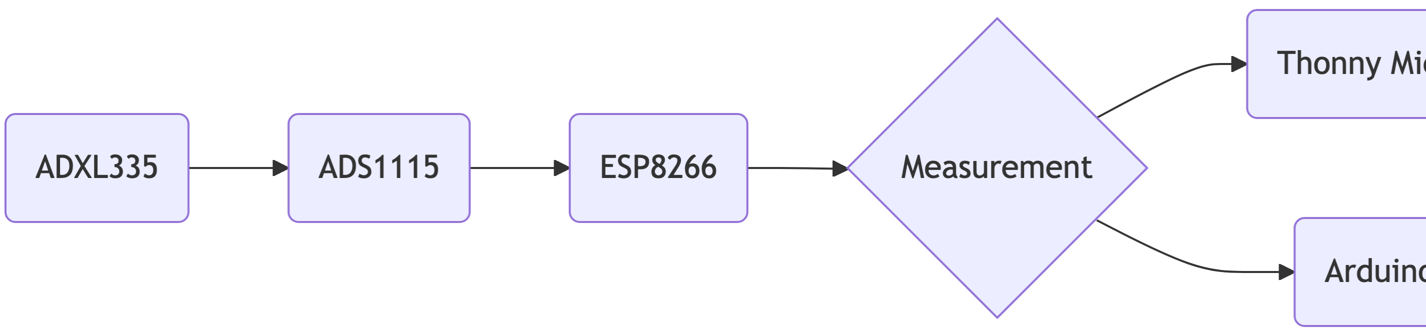


Figure 1.1.: Modular board-level sensor system.

- System level, behavioural model

  - Matlab/Simulink,
  - Python

- PCB level

  - ESP8266 NodeMCU,
  - TIs ADS1115,
  - ADs ADXL335

- IC level, SPICE with behavioural blocks, e.g. OTA and comparator

  - IIC-OSIC-TOOLS IHP130-based analog and digital chip design

- **Final Oral Exam/Project Presentation**

1.12. Course Prerequisites

- Fundamentals of linux operating systems

- Fundamentals of microelectronics

  - Device physics and models
  - Transistor level analog circuits, elementary gain stages

- Fundamentals of analog circuit design

  - Operational amplifier
  - Active filter design
  - Noise analysis
  - Switched-capacitor techniques

- Prior exposure to SPICE, Matlab, Python or equivalent.

1.13. Brave New World

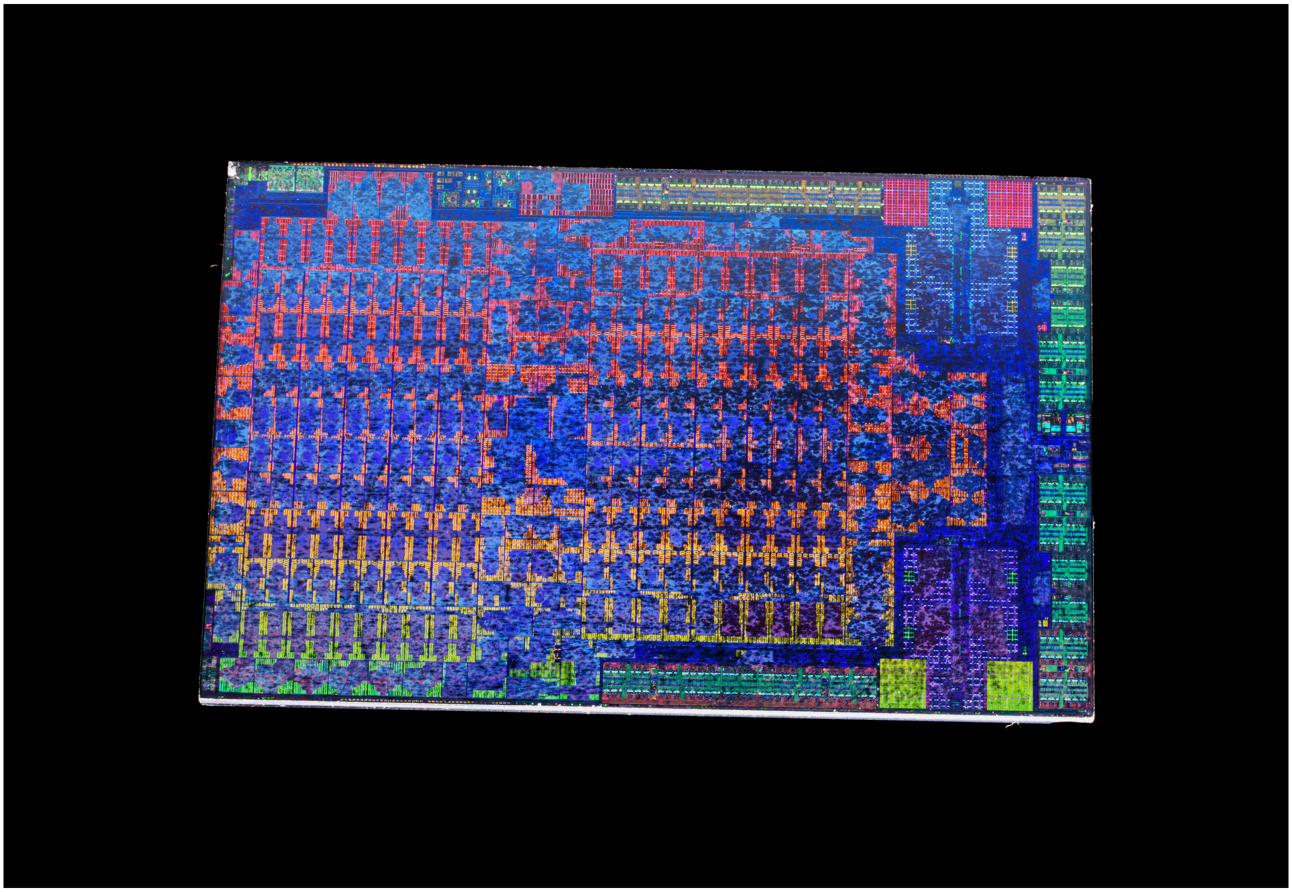


Figure 1.2.: AMD Jaguar APU (CPU/GPU), 16 nm, 325 sqmm, 2016

1.14. From Sand to Silicon (Infineon, Dresden)

https://youtu.be/bor0qLifjz4?list=PLO_wT97BGA6xC6hNy9VGtt1bKwVuQXI5B

1.15. Sand to Silicon (GlobalFoundries, Desden)

https://www.youtube.com/embed/UvluuAIiA50?list=PLO_wT97BGA6xC6hNy9VGtt1bKwVuQXI5B

1.16. FinFET (Intel)

https://www.youtube.com/embed/_VMYPLXnd7E

1.17. TSMC Fab (Next Gen 7/5 nm)

https://www.youtube.com/embed/Hb1WDxSoSec

1.18. Once upon a time ...

Figure 1.3.: 1906 Electron Tube

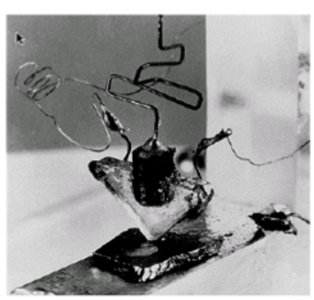


Figure 1.4.: 1947 1st Transistor, Bell Labs

1.19. First IC and today's chips

Figure 1.5.: 1958 Jack Kilby's 1st IC

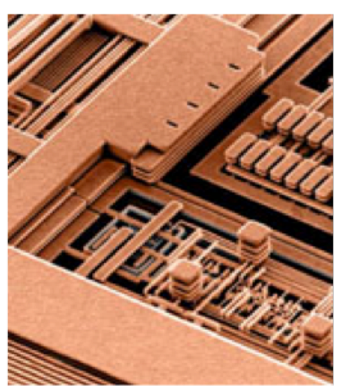


Figure 1.6.: Modern IC

1.20. Packaging Densities

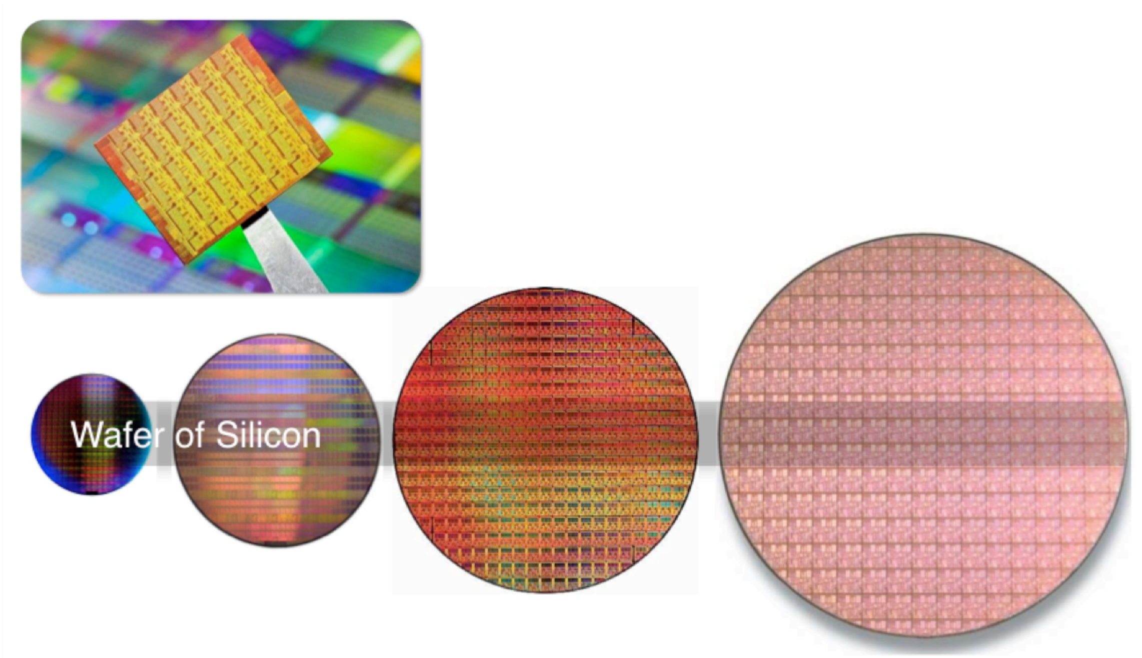


Figure 1.7.: Wafer generations

1.21. Moore's Law

https://www.youtube.com/embed/basGrfRDqts?list=PLO_wT97BGA6xC6hNy9VGtt1bKwVuQX I5B

1.22. System Hierarchy

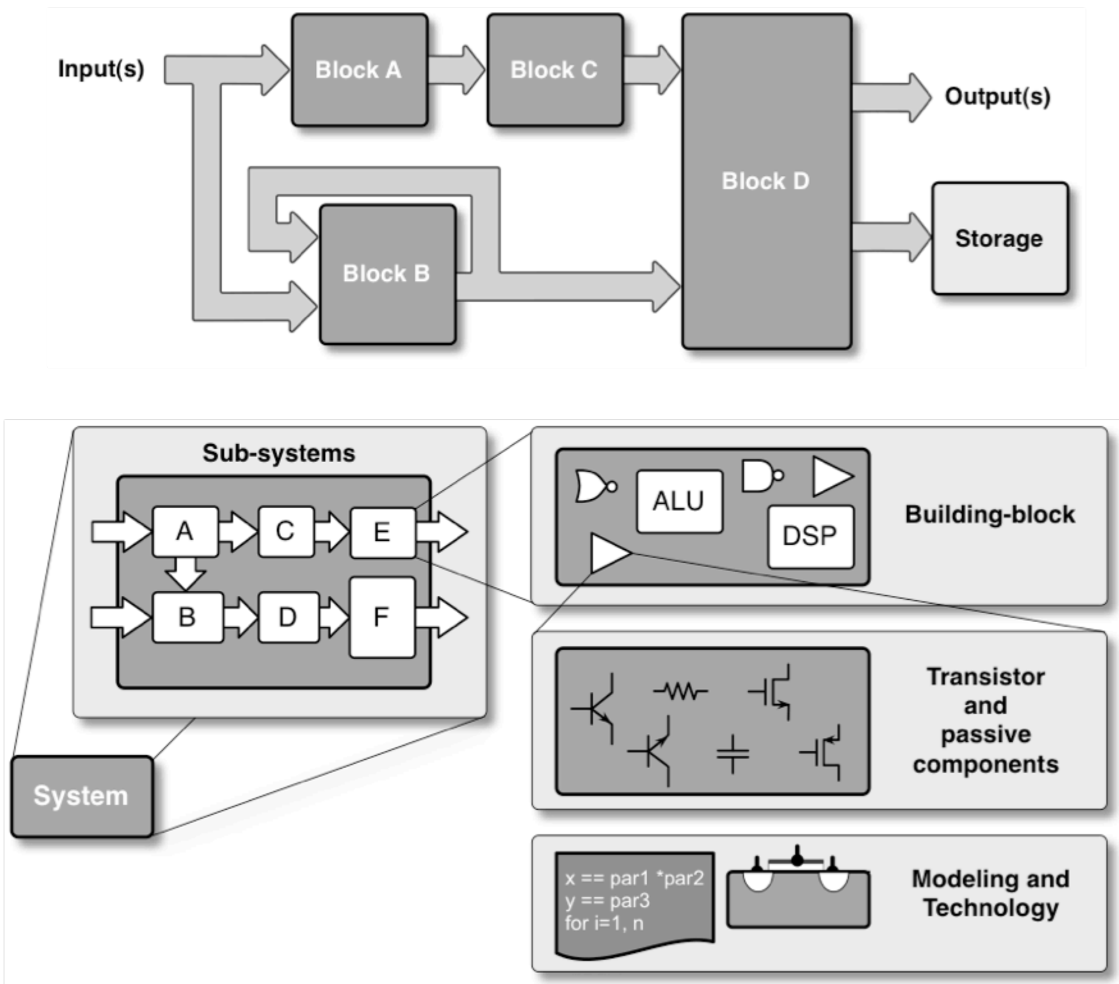


Figure 1.8.: Blocks of an electronic system.

- Use hierarchy to describe complex systems
- Devide and conquer

1.23. System Assembly

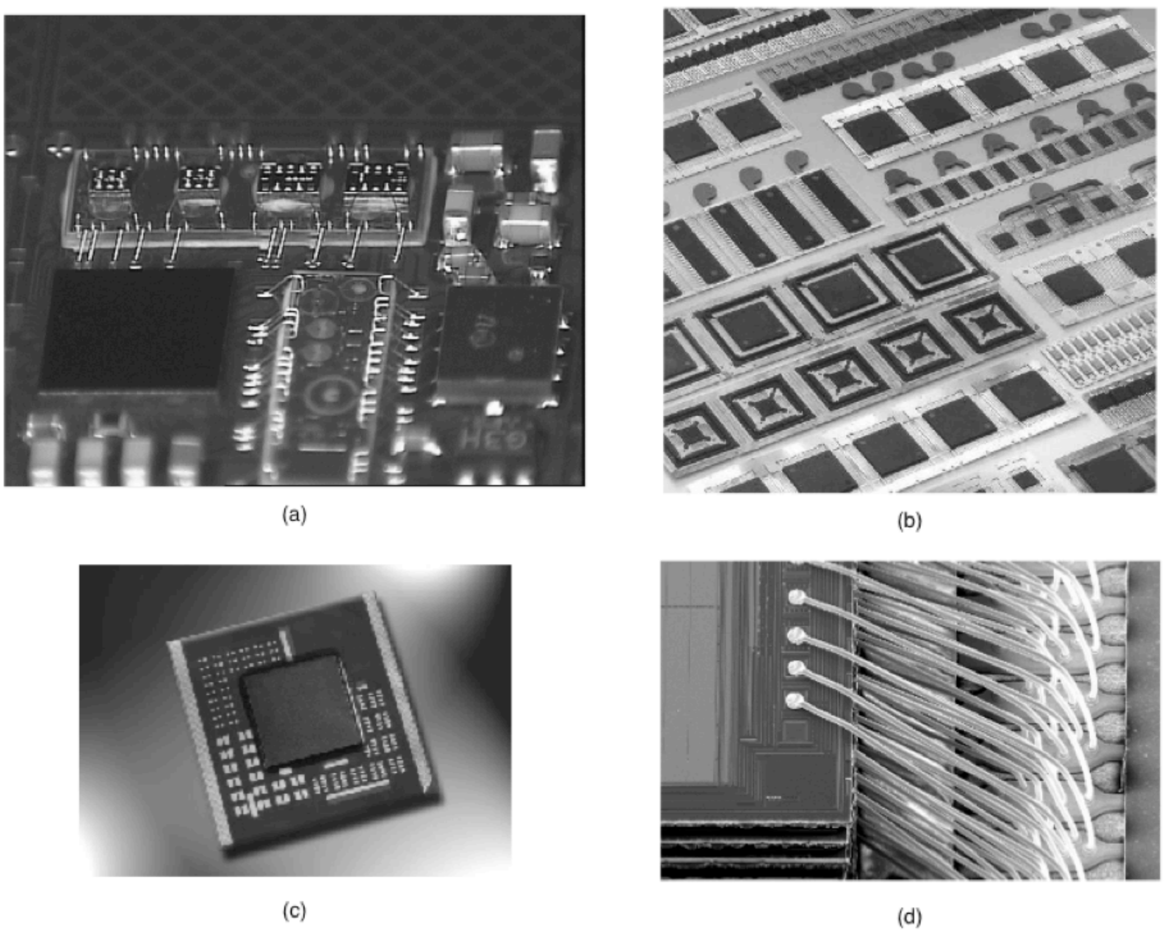


Figure 1.9.: Bottom-up Prozess, Integration.

1.24. Interfacing

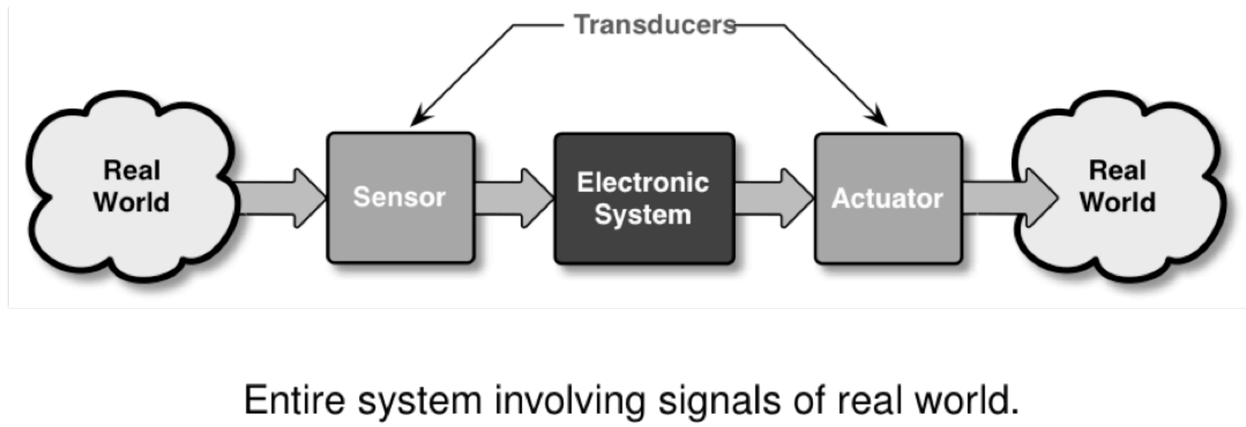


Figure 1.10.: Interfacing.

1.25. Meeting a System (1)

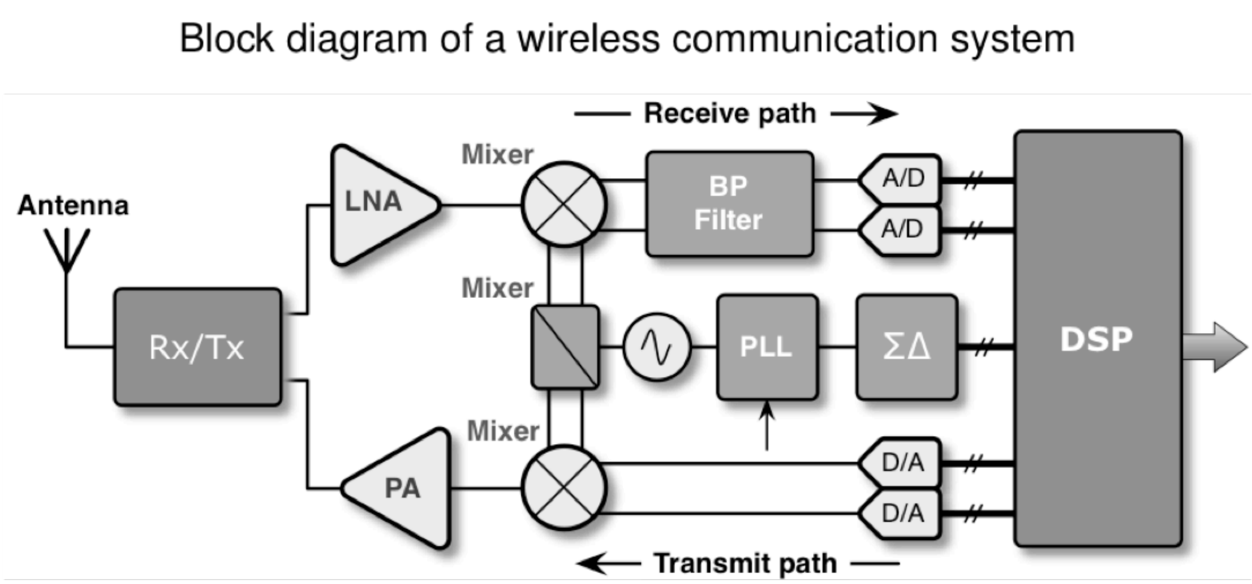
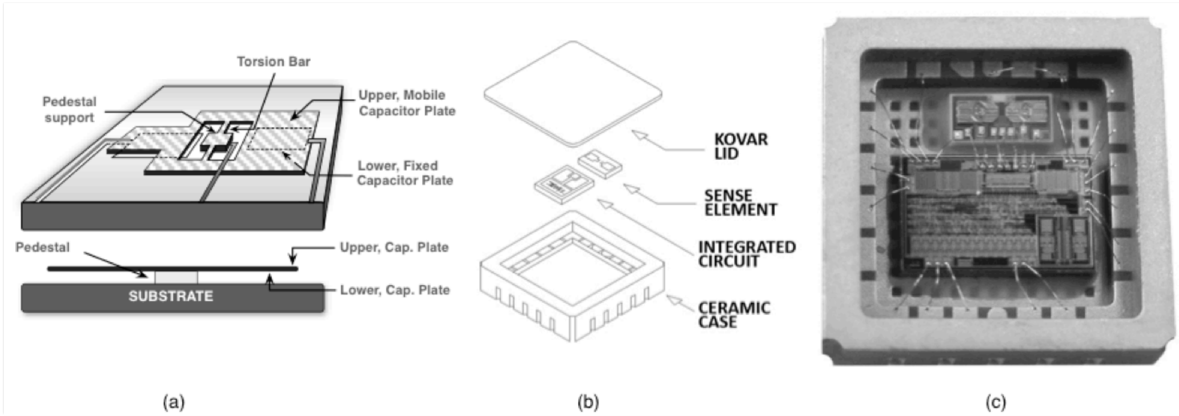


Figure 1.11.: Wireless Communication System.

1.26. System in a Package (SiP)



(a) Micro structure of an accelerometer.

(b) Assembling diagram of the system-on- package.

(c) Microphotograph. (*Courtesy of Silicon Designs, Inc.*).

Figure 1.12.: Accelerometer.

1.27. You will become an expert

Indicators.

- Background Knowledge
  - System Knowledge, Architecture, Processing, Implementation
- Subconscious Knowledge
  - Memorized experiences of success stories and dead ends
- Special Knowledge
  - Dicipline related knowledge, e.g. physics, hardware, software
- Teamwork
  - Communication abilities, reporting and presentation
- Creativity
- Tool-Knowlege

1.28. Views on Hardware

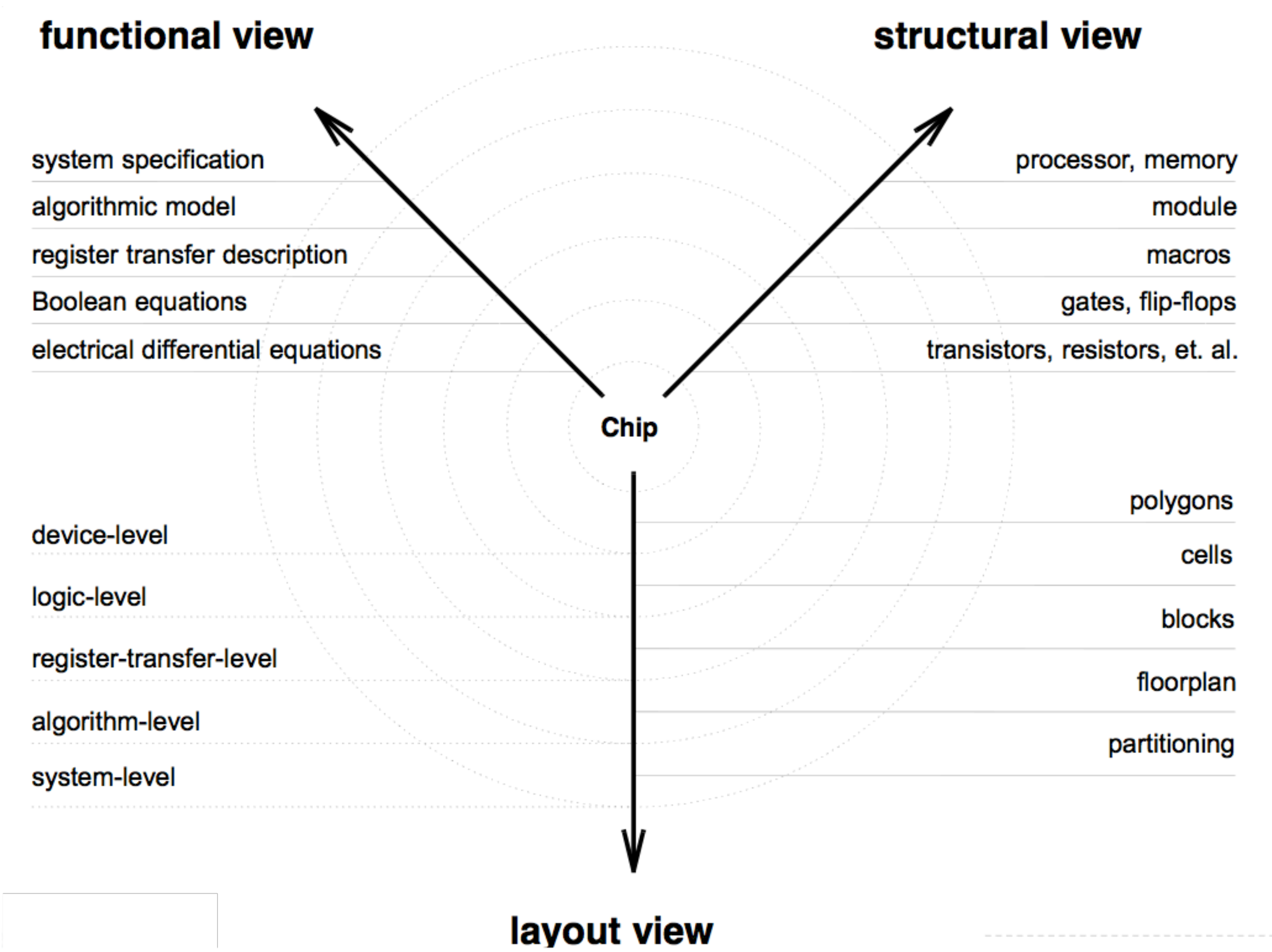


Figure 1.13.: (c) M. Ortmanns, Univ. Ulm.

1.29. Sustainable Electronics ...

https://www.youtube.com/embed/7S5IuaKiZIY

1.30. Why it is worth ...

https://www.youtube.com/embed/SwPGxwBZw6I

1.31. Let's go to the beach ...

https://www.youtube.com/embed/ekkJlQf-K4I

Bibliography

Boser, Bernhard E. 2003. "EECS247: Analog-Digital Interface Integrated Circuits." University of California Berkeley: Course notes.

Murmann, Boris. 2011. "EE315B: VLSI Data Conversion Circuits." Stanford University, Dept. of Electrical Engineering, California, U.S.: Course notes reader.

Schreier, Richard, and Gabor C. Temes. 2004. *Understanding Delta-Sigma Data Converters*. Wiley-IEEE Press.

Part II.

Lab

2. Model-Based Systems Engineering (MBSE) of an Inertial Sensor System and IC Design

This winter term, the defining idea of the CEMS course is a modular board-level sensor system consisting of ADXL335 accelerometer, ADS1115 ADC and ESP8266 NodeMCU. The ADC module has to be replaced by a custom IC design.

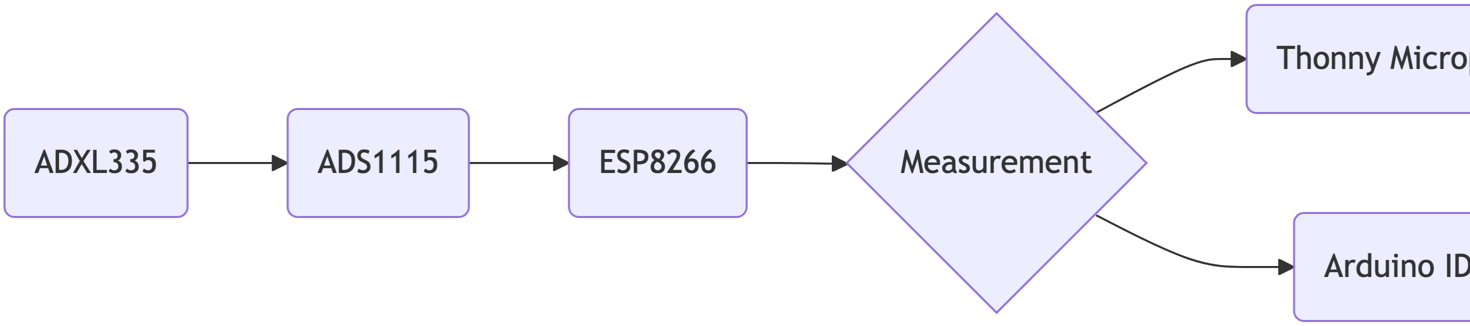


Figure 2.1.: Modular board-level sensor system.

Table 2.1.: Specifications of selected ADCs taken from (Schreier and Temes 2004), (Boser 2003) and (Murmann 2011).

Spec		Audio	Example	ADS1115
Dynamic Range	DR	16 Bits (98 dB)	16 Bits (98 dB)	16 Bits (98 dB)
Signal Bandwidth	B, f_B	20 kHz	1 kHz	215 Hz
Nyquist Freqeuncy	f_N	44.1 kHz	2 kHz	430 Hz
Modulator Order	L	5	2	2
Oversampling Ratio	$M = f_s/f_N$	64	512	512
Sampling Frequency	f_s	2.822 MHz	1.024 MHz	220 kHz
Supply Voltage	V_{DD}	3 V	3 V	3 V

- System level, behavioural model
  - Matlab/Simulink,
  - Python
- PCB level

  - ESP8266 NodeMCU,
  - TIs ADS1115,
  - ADs ADXL335

- IC level, SPICE with behavioural blocks, e.g. OTA and comparator

  - IIC-OSIC-TOOLS IHP130-based analog and digital chip design

2.1. Design Project Flow

- Literature research in journals, professional (serious) internet forums (e.g. application notes of semiconductor companies) and library
- Set-up bibliography, e.g. JabRef, Citavi
- Concept of your system

  - Partitioning
  - Functions
  - Work packages

- Design, implementation and validation

  - Mathmatical description, e.g. Matlab/Simulink model
  - SPICE modeling and simulation, LTspice and ngspice circuits
  - Data analysis and validation, Serial monitor