Msc. Microsystems Engineering - Introduction to the programme

Prof. Dr. Jürgen Wilde

30 October 2020
The technology
A macrosystem

The Airbus A380
- Approximately 1 Million single parts!
  • One Wing: 32,000 parts
- Costs: $ 275 Millions
  • Average per single part $ 275
- High effort for single part fabrication

Can you imagine such a system with 2 Million parts?
A microsystem

The DMD
- Digital Micro-mirror Device
- 1.6 cm x 1.6 cm
- 508,800 mirrors 17 µm x 24 µm
- ~ 2.2 million parts
- Price: ~ € 2 000
- Price / part: < 0.1 Cent
- Mass fabrications

Microsystems
- Many functions
- Small volume
Microsystems are small

A hair, on the same scale. Diameter: \( \sim 50 \, \mu m \)
A huge variety in microsystems
Microsystems are everywhere

- **Medicine**
  - Minimally-invasive surgery
  - Diagnostics

- **Communications**
  - Fiber optics
  - Mobile phones

- **Consumer**
  - Autonomous networks
  - Sensors

- **Industry**
  - Process management
  - Instrumentation

- **Automobile**
  - Rotation rate sensors
  - Airbags
The career
Studies: technical skills

Educational goal:
- To graduate students who can go from idea to product

The required skills: The challenge starts now
- Problem definition
- Solutions & evaluation

Design & development
- Fabrication
- Characterization & optimization
- Packaging
- System testing & qualification
- Transfer to production
- Marketing
Studies: Non-technical skills

- Technical excellence is a given...

... but graduates also need:
- Ability to work in a team
- Social competence
- Creativity
- Openness to new ideas
- Self-confidence
- Communication skills
- Entrepreneurial thinking
- Ability to motivate, oneself and others
- Leadership capabilities
Where do I go with my degree?

- Microsystems engineers become:
  - Entrepreneurs, technicians, engineers, group leaders, managers, CEOs, astronauts,…

- Potential employers:
  - Large & small companies of all types
  - Startups and spin-offs

- What do employers want?
  - Potential for development
  - Ability to learn
  - Communications ability (in English and German!)
  - Experience, experience, experience
  - Particular skills? Not so much…
The department
Faculty of Engineering

- Faculty in operation since 1995
- Department of Computer Science (IIF)
  - 19 professors / ~ 840 students
- Department of Microsystems Engineering (IMTEK)
  - 22 professors / ~ 830 students
- Department of Sustainable Systems Engineering (INATECH)
  - 7 professors / ~ 250 students
MEMS Applications
Prof. Dr. Roland Zengerle
Assembly and Packaging Technology
Prof. Dr. Jürgen Wilde
Bio- and Nano-Photonics
Prof. Dr. Alexander Rohrbach
Biomedical Microtechnology
Prof. Dr. Thomas Stieglitz
Biomicrotechnology
Prof. Dr. Ulrich Egert
Chemistry and Physics of Interfaces
Prof. Dr. Jürgen Rühe
Design of Microsystems
Prof. Dr. Peter Woias
Electrical Instrumentation
Prof. Dr. Leonhard Michael Reindl
Gas Sensors
Prof. Dr. Juergen Woellenstein
Materials Process Technology
Prof. Dr. Thomas Hanemann
Micro- and Material Mechanics
Prof. Dr. Christoph Eberl

Microactuators
Prof. Dr. Ulrike Wallrabe
Microelectronics
Prof. Dr. Yiannos Manoli
Micro-optics
Prof. Dr. Hans Zappe
Microsystems Materials
Prof. Dr. Oliver Paul
Nanotechnology
Prof. Dr. Margit Zacharias
Optical Systems
Prof. Dr. Carsten Buse
Sensors
Prof. Dr. Gerald Urban
Simulation
Prof. Dr. Lars Pastewka
Smart Systems Integration
Prof. Dr. Alfons Dehé
Systems Theory
Prof. Dr. Moritz Diehl
Process Technology
Prof. Dr. Bastian E. Rapp
The curriculum
Structural principles

- MSc. Program = 120 ECTS
- ~ 30 ECTS per semester
- 1 ECTS = 30 hours work load
- Mandatory courses are offered every other semester.
- Exams are offered every semester.
- The exam regulations stipulate which courses are to be completed to get the degree, but you can decide when you want to take which course and exam.
- It is allowed to study more than 4 semesters.
Modules in the study program

- All programs are organized in modules.
- A module consists of one or several courses and course work.

**Module Components**
- Lectures – German: Vorlesung (V)
- Exercises – German: Übung (Ü)
- Laboratories – German: Praktikum (Pr) oder Praktische Übung (PrÜ)
- Seminars – German: Seminar (S)
Course work

- **Non-graded course work ("Studienleistungen", SL)**
  - Exercises, reports, mid-term exams…
  - Are not part of your final grade, but may be part of a module (for example weekly exercise sheets)
  - May be graded, or only “pass” or “fail”
  - Unlimited number of attempts

- **Graded course work ("Prüfungsleistungen", PL)**
  - Written or oral exams, reports, presentations,…
  - Are always graded and count into your final grade
  - Limited number of attempts
## Mandatory modules I

<table>
<thead>
<tr>
<th>Module</th>
<th>Type</th>
<th>Exam</th>
<th>ECTS</th>
<th>Sem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microelectronics</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Micro-mechanics</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>MST Design Lab I</td>
<td>La</td>
<td>?</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Micro-optics</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Sensors</td>
<td>Le+La</td>
<td>Written exam</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>MST Technologies and Processes</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Probability and Statistics</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

Le = Lecture, E = Exercise, La = Lab course
## Mandatory modules II

<table>
<thead>
<tr>
<th>Module</th>
<th>Type</th>
<th>Exam</th>
<th>ECTS</th>
<th>Sem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal Processing</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Assembly and Packaging Tech.</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Biomedical Microsystems</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Micro-actuators</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Micro-fluidics</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Probability and Statistics</td>
<td>Le+E</td>
<td>Written exam</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Master thesis</td>
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<td>Thesis and pres.</td>
<td>30</td>
<td>4</td>
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<td><strong>Total Mandatory Modules</strong></td>
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<td><strong>58</strong></td>
<td></td>
<td></td>
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</tbody>
</table>

Le = Lecture, E = Exercise, La = Lab course
Choose 2 areas, minimum 9 ECTS max. 23 ECTS in each of them.

<table>
<thead>
<tr>
<th>Concentration areas</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuits and Systems</td>
<td>9-23</td>
</tr>
<tr>
<td>Design and Simulation</td>
<td>9-23</td>
</tr>
<tr>
<td>Life Sciences: Biomedical Engineering</td>
<td>9-23</td>
</tr>
<tr>
<td>Life Sciences: Lab-on-a-chip</td>
<td>9-23</td>
</tr>
<tr>
<td>Materials</td>
<td>9-23</td>
</tr>
<tr>
<td>MEMS Processing</td>
<td>9-23</td>
</tr>
<tr>
<td>Photonics</td>
<td>9-23</td>
</tr>
<tr>
<td>Sensors and Actuators</td>
<td>9-23</td>
</tr>
<tr>
<td>Personal Profile</td>
<td>9-23</td>
</tr>
<tr>
<td>Total Elective Modules</td>
<td>32</td>
</tr>
</tbody>
</table>
## MSE – Elective modules

<table>
<thead>
<tr>
<th>Circuits and systems</th>
<th>Design and Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Storage and Conversion using Fuel Cells</td>
<td>Embedded Control Laboratory</td>
</tr>
<tr>
<td>Mixed Signal CMOS Circuit Design</td>
<td>Flight Control Laboratory</td>
</tr>
<tr>
<td>Advanced embedded Systems Laboratory</td>
<td>Modelling and System Identification</td>
</tr>
<tr>
<td>Advanced Laboratory in Microcontroller</td>
<td>Numerical Optimisation</td>
</tr>
<tr>
<td>Power Electronics: Devices and Concepts</td>
<td>Numerical Optimisation Software Project</td>
</tr>
<tr>
<td>Embedded Control Project</td>
<td>Optimal Control and Estimation</td>
</tr>
<tr>
<td>Microcontroller Techniques</td>
<td>Optimal and Model Predictive Control</td>
</tr>
<tr>
<td>Power Electronic Circuits and Devices</td>
<td>Race Car Control Lab</td>
</tr>
<tr>
<td>RF- and Microwave Devices and Circuits</td>
<td>VLSI System Design</td>
</tr>
<tr>
<td>RF- and Microwave Systems Design course</td>
<td>Wind Energy Systems</td>
</tr>
<tr>
<td>Systems Theory and automatic Control II</td>
<td></td>
</tr>
<tr>
<td>Reliability Engineering</td>
<td></td>
</tr>
</tbody>
</table>
# MSE – Elective modules

## Life Sciences: Biomedical Engg.
- Analyse von Life Science Hochdurchsatzdaten mit Galaxy
- Selected Problems in Biosignal Processing
- Biofunctional Materials - for medical microsystems and healthcare
- Biologie für Ingenieure
- Bionic Sensors - Laboratory
- Biomedical Instrumentation I
- Biomedical Instrumentation II
- Biomedical Instrumentation - Laboratory
- Biophysics of the cell
- Ethical Aspects of Neurotechnology
- Fundamentals of electrical stimulation
- Introduction to physiological Control Systems
- Implant Manufacturing Technologies
- Signal processing and analysis in brain signals
- Microsystems technology in Medicine
- Nanobiotechnology
- Neurophysiology - Laboratory
- Neuroprosthetics
- Neuroscience for Engineers

## Life Sciences: Lab-on-a-chip
- Bioactive Polymer Surfaces
- Biofuel Cells and Bioelectrochemical Systems
- BioMEMS
- Biotechnology for Engineers I: Introduction, Molecular- and Microbiology
- Biotechnology for Engineers II
- Interfaces for Bioanalytical Systems
- Introduction to data driven life sciences
- Basics in Molecular Biology for Bioanalytical Systems
- Microfluidics II: Miniaturize, automate and parallelize biochemical analysis
- Surface Analysis
# MSE – Elective modules

<table>
<thead>
<tr>
<th><strong>Materials</strong></th>
<th><strong>MEMS Processing</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioactive Polymer Surfaces</td>
<td>Lithography</td>
</tr>
<tr>
<td>Bioactive Polymer Surfaces with seminar</td>
<td>Electrochemical production technologies</td>
</tr>
<tr>
<td>Bioinspired functional materials</td>
<td>CMOS-Integrated Microsystems</td>
</tr>
<tr>
<td>Computational physics: materials science</td>
<td>Advanced Assembly and Packaging Technology</td>
</tr>
<tr>
<td>Electrochemical Energy Applications: Batteries</td>
<td>Lithography</td>
</tr>
<tr>
<td>Semiconductor Technology and Devices</td>
<td>Advanced Silicon Technology</td>
</tr>
<tr>
<td>Ceramic Materials for microsystems</td>
<td>Micro-Acoustical Transducers</td>
</tr>
<tr>
<td>Ceramic technology in microsystems</td>
<td>Microstructured Polymer Components</td>
</tr>
<tr>
<td>Physics of Failure</td>
<td>Mold Flow Simulation for Replication Processes</td>
</tr>
<tr>
<td>Contact, Adhesion, Friction</td>
<td>Nanotechnology</td>
</tr>
<tr>
<td>Continuum Mechanics I with exercises</td>
<td>Advanced Engineering</td>
</tr>
<tr>
<td>Continuum Mechanics II with exercises</td>
<td>Surface Analysis Laboratory</td>
</tr>
<tr>
<td>Mechanical Properties and Degradation Mechanisms</td>
<td>Silicon-based Neural Technology</td>
</tr>
<tr>
<td>Molecular Statics and Dynamics</td>
<td>Surface coating Techniques</td>
</tr>
<tr>
<td>Nanomaterials</td>
<td></td>
</tr>
<tr>
<td>Nano - Laboratory</td>
<td></td>
</tr>
<tr>
<td>Particle Methods in Engineering</td>
<td></td>
</tr>
<tr>
<td>Surface Analysis</td>
<td></td>
</tr>
<tr>
<td>Polymer Chemistry for Engineers</td>
<td></td>
</tr>
<tr>
<td>Polymers in Membrane Technology</td>
<td></td>
</tr>
<tr>
<td>From Microsystems to the Nanoworld</td>
<td></td>
</tr>
<tr>
<td>Dynamics of Materials</td>
<td></td>
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</tbody>
</table>
## MSE – Elective modules

<table>
<thead>
<tr>
<th><strong>Photonics</strong></th>
<th><strong>Sensors and Actuators</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Topics in Micro-Optics</td>
<td>Thin Film Analyses and Nanoscale Measurement Technologies</td>
</tr>
<tr>
<td>Lasers</td>
<td>Bionic Sensors</td>
</tr>
<tr>
<td>Basic Optics Lab</td>
<td>Wireless Sensor Networks</td>
</tr>
<tr>
<td>Basic and Advanced Optics Lab</td>
<td>Wireless Sensor Systems</td>
</tr>
<tr>
<td>Optical Materials</td>
<td>Disposable sensors</td>
</tr>
<tr>
<td>Optical Properties of Micro and Nano Structures</td>
<td>Electrochemical energy applications: Li-ion batteries and fuel cells</td>
</tr>
<tr>
<td>Optical Trapping and Particle Tracking</td>
<td>Energy harvesting</td>
</tr>
<tr>
<td>Optical MEMS</td>
<td>Gas Sensors</td>
</tr>
<tr>
<td>Optical Measurement Techniques</td>
<td>Power Electronics for E-Mobility</td>
</tr>
<tr>
<td>Optical Micro-Sensors</td>
<td>Electrochemical Methods for Engineers</td>
</tr>
<tr>
<td>Optoelectronics</td>
<td>Mikroaktorik für Mikrosystemtechniker</td>
</tr>
<tr>
<td>Photonic Microscopy</td>
<td>Microacoustics</td>
</tr>
<tr>
<td>Photovoltaic Energy Conversion for engineers</td>
<td>Piezoelectric and dielectric transducers</td>
</tr>
<tr>
<td>Photovoltaic Energy Conversion for engineers II</td>
<td>Quantum mechanics for engineers</td>
</tr>
<tr>
<td>Spektroskopische Methoden</td>
<td>Electronics Signal Processing for Sensors and Actuators</td>
</tr>
<tr>
<td>Wave Optics</td>
<td>Thermoelektrik</td>
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<tr>
<td></td>
<td>Compound semiconductor devices</td>
</tr>
</tbody>
</table>
WS 20/21: All courses (except for lab courses) can be taken online

Some lecturers will offer on-campus sessions in addition to the online offer

Online lectures: Either livestream or recorded lectures

Online exercises: Students will send or upload the exercises they solved. Lecturer will give individual feedback and/or offer Q&A sessions or online forums

More detailed information will be provided by each lecturer for his/her course by email or via ILIAS

Written exams can only be taken on-campus
Faculty of Engineering:
https://www.tf.uni-freiburg.de/en/corona

University:
https://www.studium.uni-freiburg.de/en?set_language=en

Student Services (SWFR):
https://www.swfr.de/en/corona-faqs/
# MSE courses, first semester

<table>
<thead>
<tr>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-12</td>
<td>10-12</td>
<td>8-10 Probability &amp; Stat. Lecture 051-03-026</td>
<td>8-10 Micro-electronics Exercises 101 00 036</td>
<td></td>
</tr>
<tr>
<td>Micromechanics Lecture online</td>
<td>Micro-optics Lecture 101 00 036</td>
<td>10-12 Micro-electronics Lecture 101 00 036</td>
<td>10-12 Probability &amp; Stat. Exercises 051-03-026</td>
<td></td>
</tr>
<tr>
<td>10-12</td>
<td>13-14</td>
<td>13-14 Sensors Lecture Online</td>
<td>12-14 MST Design Lab ) Lab course 082 00 006</td>
<td>10-12 Micromechanics Exercises 101 00 036</td>
</tr>
<tr>
<td>MST Technologies &amp; Processes Exercises</td>
<td>Sensors Lecture Online</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>14-16</td>
<td>14-16</td>
<td>14-16 MST Technologies &amp; Processes, lecture</td>
<td>14-16 Sensors Lab 078 00 035</td>
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</tr>
<tr>
<td>Sensors Lecture Online</td>
<td>MST Technologies &amp; Processes, lecture</td>
<td></td>
<td>Micro-optics Exercises</td>
<td></td>
</tr>
<tr>
<td>16-18</td>
<td>16-18</td>
<td>16-18 Sensors Lab 078 00 035</td>
<td>16-18 Sensors Lab 078 00 035</td>
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<td>MST Design Lab I Lecture 051 03 026</td>
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<tr>
<td>18-20</td>
<td>18-20</td>
<td>18-20 Sensors Lab 078 00 035</td>
<td></td>
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</tr>
</tbody>
</table>
Exams: The most important rules

- In addition to registering for a module, you need to **register for every exam** you want to take: https://www.tf.uni-freiburg.de/en/studies-and-teaching/a-to-z-study-faq/de-registration-of-exams
- If **failed**, you can repeat every exam once. Two exams can be repeated twice.
- If you fail an exam, you will automatically be registered for the **retake** in the following semester.
- You can only **withdraw from an exam** if you are ill or if there is an emergency in your family. https://www.tf.uni-freiburg.de/en/studies-and-teaching/a-to-z-study-faq/withdrawl-from-exams
- For more details, make sure to read the **exam regulations**.
Plagiarism

- Plagiarism is:
  - Using someone else’s texts, pictures, reports, data, solutions, whatever….
  - … without giving the source

- Sources include:
  - Books, the internet, colleagues, …

- To make it clear:
  - Plagiarism is illegal

- The simple „if...then“ loops:
  - If you plagiarize...(once)
  - … then you fail
  - If you plagiarize repeatedly (=twice)
  - … then your academic career is over.
Mentoring

- Every student has a faculty mentor
  - A professor as a contact person
  - Assigned by the Dean of Studies
- Student’s contact for:
  - Problems, questions, clarifications, job searches, recommendations, or just general advising
After graduation
Apply for a job

- **In Industry**
  - Find out what you like during your MSc program
  - Use job portals and company websites to monitor the market
  - Visit career workshops to gather tips how to apply
  - Go to recruiting fairs
Phd. as research assistant

- At the university:
  - Perform a research project (on your own)
  - Look for an open position
  - Apply
  - Get paid for the PhD project
  - Overtake responsibility as project assistant
  - Support your professor with respect to educational tasks
  - Duration: 3-5 years
Contact persons I

- **Dean of studies:** Prof. Jürgen Wilde
  - juergen.wilde@imtek.de
  - 203 7291

- **Program coordinator:** Ursula Epe
  - studiengangkoordination.mst@imtek.uni-freiburg.de
  - 203 97940

- **Student advisers:**
  - studienberatung@imtek.de
    - Dr. Jochen Kieninger
      - 203 7265
    - Dr. Oswald Prucker
      - 203 7164
Contact persons II

- Examination office
  - Anne-Julchen Müller
    - pruefungsamt@tf.uni-freiburg.de
    - 203 8083
  - Susanne Storck
    - pruefungsamt@tf.uni-freiburg.de
    - 203 8083
Thank you very much for your attention!