Msc. Microsystems Engineering - Introduction to the programme

Prof. Dr. Jürgen Wilde

11 October 2021
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: ~ 50 µm
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**
  - Gyroscope
  - Airbags
The career
Studies: technical skills

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

- **The required skills:**
  - Problem definition
  - Solutions & evaluation

- **Design & development**
  - Fabrication
  - Characterization & optimization
  - Packaging
  - System testing & qualification
  - Transfer to production
  - Marketing

The challenge starts now
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 can 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
IMTEK-Professors
<table>
<thead>
<tr>
<th>Research Areas</th>
<th>Professors</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEMS Applications</td>
<td>Prof. Dr. Roland Zengerle</td>
</tr>
<tr>
<td>Assembly and Packaging Technology</td>
<td>Prof. Dr. Jürgen Wilde</td>
</tr>
<tr>
<td>Bio- and Nano-Photonics</td>
<td>Prof. Dr. Alexander Rohrbach</td>
</tr>
<tr>
<td>Biomedical Microtechnology</td>
<td>Prof. Dr. Thomas Stieglitz</td>
</tr>
<tr>
<td>Biomicrotechnology</td>
<td>Prof. Dr. Ulrich Egert</td>
</tr>
<tr>
<td>Chemistry and Physics of Interfaces</td>
<td>Prof. Dr. Jürgen Rühe</td>
</tr>
<tr>
<td>Design of Microsystems</td>
<td>Prof. Dr. Peter Woiias</td>
</tr>
<tr>
<td>Electr. Instrumentation &amp; Embedded Sys.</td>
<td>Prof. Dr. Stefan Rupitsch</td>
</tr>
<tr>
<td>Gas Sensors</td>
<td>Prof. Dr. Juergen Woellenstein</td>
</tr>
<tr>
<td>Materials Process Technology</td>
<td>Prof. Dr. Thomas Hanemann</td>
</tr>
<tr>
<td>Micro- and Material Mechanics</td>
<td>Prof. Dr. Christoph Eberl</td>
</tr>
<tr>
<td>Microactuators</td>
<td>Prof. Dr. Ulrike Wallrabe</td>
</tr>
<tr>
<td>Microelectronics</td>
<td>Deputy: Dr. Matthias Keller</td>
</tr>
<tr>
<td>Micro-optics</td>
<td>Prof. Dr. Hans Zappe</td>
</tr>
<tr>
<td>Microsystems Materials</td>
<td>Prof. Dr. Oliver Paul</td>
</tr>
<tr>
<td>Nanotechnology</td>
<td>Prof. Dr. Margit Zacharias</td>
</tr>
<tr>
<td>Optical Systems</td>
<td>Prof. Dr. Carsten Buse</td>
</tr>
<tr>
<td>Sensors</td>
<td>Prof. Dr. Gerald Urban</td>
</tr>
<tr>
<td>Simulation</td>
<td>Prof. Dr. Lars Pastewka</td>
</tr>
<tr>
<td>Smart Systems Integration</td>
<td>Prof. Dr. Alfons Dehé</td>
</tr>
<tr>
<td>Systems Theory</td>
<td>Prof. Dr. Moritz Diehl</td>
</tr>
<tr>
<td>Process Technology</td>
<td>Prof. Dr. Bastian E. Rapp</td>
</tr>
</tbody>
</table>
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 the respective 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 judged only as “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, normally only 2
### Mandatory modules in MSc MSE

<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>6</td>
<td>1</td>
</tr>
<tr>
<td>Micro-mechanics</td>
<td>Le+E</td>
<td>Written exam</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>MST Design Laboratory I for Microsystems Engineering</td>
<td>La</td>
<td>Studien-leistung</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>MST Technologies and Processes</td>
<td>Le+E</td>
<td>Studien-leistung</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Signal Processing</td>
<td>Le+La</td>
<td>Written exam</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Master’s Module (6 months)</td>
<td></td>
<td>Thesis + Presentation</td>
<td>27+3</td>
<td>4</td>
</tr>
</tbody>
</table>

Le = Lecture, E = Exercise, La = Lab course
## Compulsory Electives: Advanced Microsystems

Choose 5 of 8

<table>
<thead>
<tr>
<th>Module</th>
<th>Type</th>
<th>Exam</th>
<th>ECTS</th>
<th>Sem.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly and Packaging Technology</td>
<td>Le+E</td>
<td>Written exam</td>
<td>6</td>
<td>1, 2 or 3</td>
</tr>
<tr>
<td>Micro-optics</td>
<td>Le+E</td>
<td>Written exam</td>
<td>6</td>
<td>1 or 3</td>
</tr>
<tr>
<td>Modelling and System Identification</td>
<td>Le+E</td>
<td>Written exam</td>
<td>6</td>
<td>1 or 3</td>
</tr>
<tr>
<td>Probability and Statistics</td>
<td>Le+E</td>
<td>Written exam</td>
<td>6</td>
<td>1 or 3</td>
</tr>
<tr>
<td>Sensors</td>
<td>Le+E</td>
<td>Written exam</td>
<td>6</td>
<td>1 or 3</td>
</tr>
<tr>
<td>Biomedical Microsystems</td>
<td>Le+E</td>
<td>Written exam</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Micro-actuators</td>
<td>Le+E</td>
<td>Written Exam</td>
<td>6</td>
<td>2</td>
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<tr>
<td>Micro-fluidics</td>
<td>Le+E</td>
<td>Written Exam</td>
<td>6</td>
<td>2</td>
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</tbody>
</table>

**Total to be selected** 30

Le = Lecture, E = Exercise, La = Lab course
Concentration Areas + Customized Courses

<table>
<thead>
<tr>
<th>Concentration areas (21-30 ECTS)</th>
<th>ECTS</th>
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</thead>
<tbody>
<tr>
<td>Circuits and Systems</td>
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</tr>
<tr>
<td>Materials and Fabrication</td>
<td></td>
</tr>
<tr>
<td>Biomedical Engineering</td>
<td>Students have to</td>
</tr>
<tr>
<td>Photonics</td>
<td>choose one</td>
</tr>
<tr>
<td></td>
<td>concentration area</td>
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<tr>
<td>Total</td>
<td>21-30</td>
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</table>

<table>
<thead>
<tr>
<th>Customized Course Selection</th>
<th>ECTS</th>
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</thead>
<tbody>
<tr>
<td>Courses from other faculties at the</td>
<td></td>
</tr>
<tr>
<td>University of Freiburg, also courses on</td>
<td></td>
</tr>
<tr>
<td>German language, scientific writing,</td>
<td>Students can</td>
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<tr>
<td>project management</td>
<td>chose</td>
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<tr>
<td>Courses from the MSc MSE program</td>
<td>9</td>
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<tr>
<td>Total</td>
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</table>
Elective modules in concentrations

Circuits and Systems

- Angewandte Sensorschaltungstechnik
- Bayesian Methods for Sensing
- CMOS MEMS
- Wireless Sensor Systems
- Energy harvesting
- Analog CMOS Circuit Design
- Mixed-Signal CMOS Circuit Design
- Flight Control Laboratory
- Advanced Assembly and Packaging Technology
- Advanced Microcontroller Lab
- Power Electronics for E-Mobility
- Micro Acoustical Transducers
- Microcontroller Techniques - Praktikum
- Model Predictive Control and Reinforcement Learning
- MST Design Lab II for Microsystems Engineering
- Numerical Optimal Control in Engineering - Project
- Numerical Optimization
- Numerical Optimization Project
- Race Car Control Laboratory
- RF- and Microwave Devices and Circuits
- RF- and Microwave Circuits and Systems
- RF- and Microwave Systems- Design Course
- Sensors and actuators circuit technology
- State Space Control Systems
- Thermoelektrik und thermische Messtechnik
- Wind Energy Systems
- Reliability Engineering

Materials and Fabrication

- Computational physics: material science
- Disposable sensors
- Electrochemical energy applications: fuel cells and electrolysis
- Electrochemical Methods for Engineers
- Energy storage and conversion using fuel cells
- Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology
- Functional Safety, Security and Sustainability: Active Resilience
- Hardware Design with the Finite-Element-Method
- Ceramic Materials for Microsystems
- Contact, Adhesion, Friction
- Continuum mechanics I with exercises
- Continuum mechanics II with exercises
- Physics of Failure
- Lithography
- Materials for Electronic Systems
- Mechanical Properties and Degradation Mechanisms
- Methods of Material Analysis
- Microstructured Polymer Components
- Nanomaterials
- Nanotechnology
- Nano - Laboratory
- Surface Analysis
- Surface Analysis Laboratory
- Optimierung
- Advanced engineering
- Polymer Processing and Microsystems Engineering
- Quantum Mechanics for Engineers
- Clean Room Laboratory for Engineers
- Quantification of Resilience
- Solar Energy
- Techniken zur Oberflächenmodifizierung / Surface coating Techniques
- Compound semiconductor devices
- From Microsystems to the Nanoworld
- Dynamics of Materials: Material Characterization
## Elective modules in concentrations

### Biomedical Engineering
- Analyse von Life Science Hochdurchsatzdaten mit Galaxy
- Selected Problems in Biosignal Processing
- Biofunctional Materials - for medical Microsystems and healthcare
- Biomedical Instrumentation I
- Biomedical Instrumentation II
- Biomedical Instrumentation - Laboratory
- BioMEMS
- Bionic Sensors
- Biophysics of cardiac function and signals
- Biophysik - Grundlagen und Konzepte
- Biotechnologie für Ingenieure I: Einführung, Molekular- Biotechnology for Engineers I: Introduction, Molecular- and Microbiology
- Biotechnology for Engineers II
- Ethical Aspects of Neurotechnology
- Fundamentals of electrical stimulation
- Introduction to data driven life sciences
- Introduction to physiological control systems
- Machine Learning
- Microfluidics II: Miniaturize, automate and parallelize biochemical analysis: From idea to product launch
- Microsystems technology in Medicine
- Nanobiotechnology
- Neurophysiology - Laboratory
- Neuroprosthetics
- Neuroscience for Engineers
- Signal processing and analysis in brain signals
- Silicon-based Neural Technology
- Implant Manufacturing Technologies
- Implant Manufacturing Technologies - Laboratory
- Biointerfaces I - Basics for Bioanalytical Systems

### Photonics
- Advanced Topics in Micro-Optics
- Lasers
- Basic Optics Lab
- Basic and Advanced Optics Lab
- Optical Materials
- Optical Properties of Micro and Nano Structures
- Optical Trapping and Particle Tracking
- Optical MEMS
- Optical Measurement Techniques
- Optical Micro-Sensors
- Optoelectronics
- Photonic Microscopy
- Photovoltaic Energy Conversion for engineers
- Photovoltaic Energy Conversion for engineers II
- Spektroskopische Methoden
- Wave Optics
WS 21/22: 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 live-stream 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
Corona Information II

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>
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<tbody>
<tr>
<td>10-12</td>
<td>10-12</td>
<td>10-12</td>
<td>10-12</td>
<td>10-12</td>
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<tr>
<td>Micromechanics Lecture</td>
<td>Micro-optics Lecture</td>
<td>Micro-electronics Lecture</td>
<td>Sensors Lecture</td>
<td>Micromechanics Exercises</td>
</tr>
<tr>
<td>HS 00 026 µ -lecture hall</td>
<td>SR 00-010/14 building 101</td>
<td>HS 00 026 µ -lecture hall</td>
<td>SR 01-009/13 Building 101</td>
<td>101 00 010/14</td>
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<tr>
<td>(building 101)</td>
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<td>(building 101)</td>
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<tr>
<td>13-14</td>
<td>12-14</td>
<td>12-14</td>
<td>12-14</td>
<td></td>
</tr>
<tr>
<td>MST Technologies &amp; Processes Exercises</td>
<td>Micro-optics Exercises SR 01-016/18 Building 101</td>
<td>Micro-optics Lecture SR 00-010/14 building 101</td>
<td>Sensors Lecture SR 01-009/13 Building 101</td>
<td>MST Design Lab I Lab course online</td>
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<tr>
<td>14-16</td>
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<td>14-16</td>
<td>14-16</td>
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<tr>
<td>Sensors Lecture</td>
<td>MST Technologies &amp; Processes, lecture</td>
<td>MST Technologies &amp; Processes, lecture SR 00-010/14 building 101</td>
<td>Micro-optics Exercises SR 00-006 Building 051</td>
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<tr>
<td>SR 01-009/13 Building 101</td>
<td>SR 00-010/14 building 101</td>
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<tr>
<td>16-18</td>
<td>16-18</td>
<td>16-18</td>
<td>16-18</td>
<td></td>
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<tr>
<td>MST Design Lab I Lecture</td>
<td>Sensors Lab 00 035 Building 078</td>
<td>Sensors Lab 00 035 Building 078</td>
<td>Sensors Lab 00 035 Building 078</td>
<td></td>
</tr>
<tr>
<td>HS 00-006, building 082</td>
<td></td>
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<tr>
<td>18-20</td>
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<tr>
<td>Sensors Lab 00 035 Building 078</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Präsentationstitel** 28
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 on 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
  - 0761-203 7291

- **Program coordination:**
  Svenja Andresen
  - studiengangkoordination.mst@imtek.uni-freiburg.de
  - 0761-203 97940

- **Student advisors:**
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      - 0761-203 7265
    - Dr. Oswald Prucker
      - 0761-203 7164
Contact persons II

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    • pruefungsamt@tf.uni-freiburg.de
    • 203 8083
  - Susanne Storck
    • pruefungsamt@tf.uni-freiburg.de
    • 203 8083
Thank you very much for your attention!