EMBEDDED SOFTWARE LABORATORY

RWTH AACHEN UNIVERSITY

# An Undergraduate Embedded Software Laboratory for the Masses

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# Outline

- Motivation
- Short Facts on the new Lab Course
- Organizational Aspects
- Evaluation Board
- Topics
- Experiences
- Summary and Outlook

# Bologna Process → Impact to Curricula

- Graduation Scheme was Adapted to Bachelor and Master of Science
- Courses have to be Rearranged
- New Courses were Established
- Analysis of Existing Curriculum was Performed

# Particular Requirements to new Courses

- Experiences with Hardware Related Issues
  - CPU and Hardware Registers
  - Interrupts
  - Memory-Models
- Getting in Practical Touch with System Software
  - Bootloader
  - Scheduling
  - Memory Management
  - Programming Paradigms (Especially Hardware Programming)

# Outline of the new Lab Course

- Mandatory 3rd Semester BSc (with no Requirements)
- Implementing an Operating System on an ATmega in C
- Practically Familiarizing with Operating Systems Algorithms
- Working with restricted hardware resources
- Testing and Documenting Code
- Teamwork
- Presenting ones Results (5 Min Presentations)

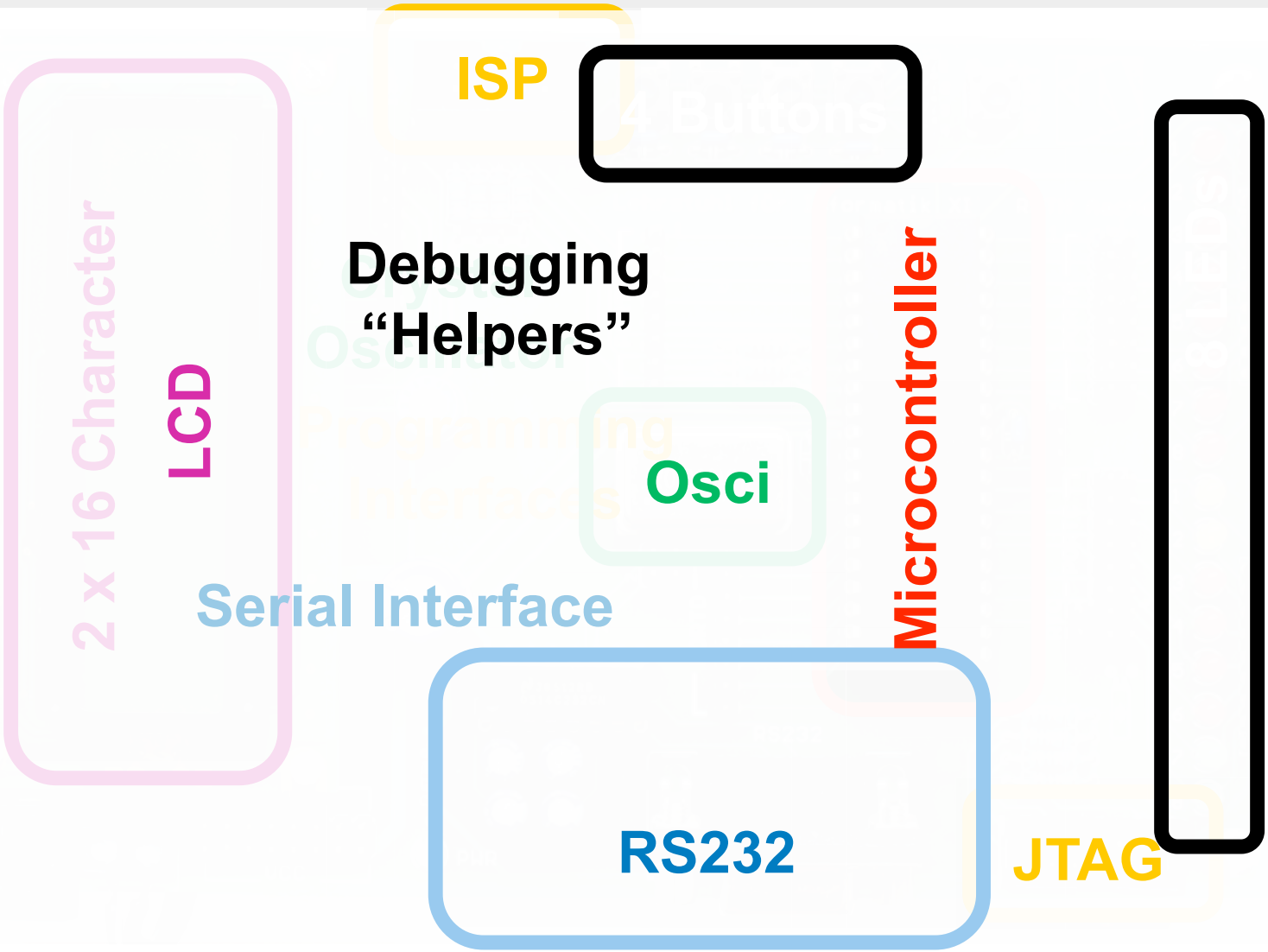
# Facts and Figures on the Lab Course

- Used Microcontroller: ATmega 644
- 2nd Year Students
- 4 ECTS Credits
  - 18 Hours of Presence Exercises
  - ~ 100 Hours of Self Studies (Homework)
- ~ 200 Students (in Teams of 2 Students)
- Experiments Spread over approx. 3.5 Months
- No Grades (just Passed of Failed)
- Established in Winter Term 2007 (3rd Time this Semester)

# Organizational Aspects

- 6 Experiments with 3 Hours of Presence Exercise each
- Guided by 1 Research Assistant and 3 Student Assistants
- Group Sizes of approx. 30 Students (15 Teams)
- Test Programs for each Experiment
- Different Ways of Supporting the Students
  - Guiding Documentations
  - Consultation-Hours
  - Moderated Bulletin Board
  - Reliable and Easy to Handle Evaluation Board
  - Testing on Real Hardware

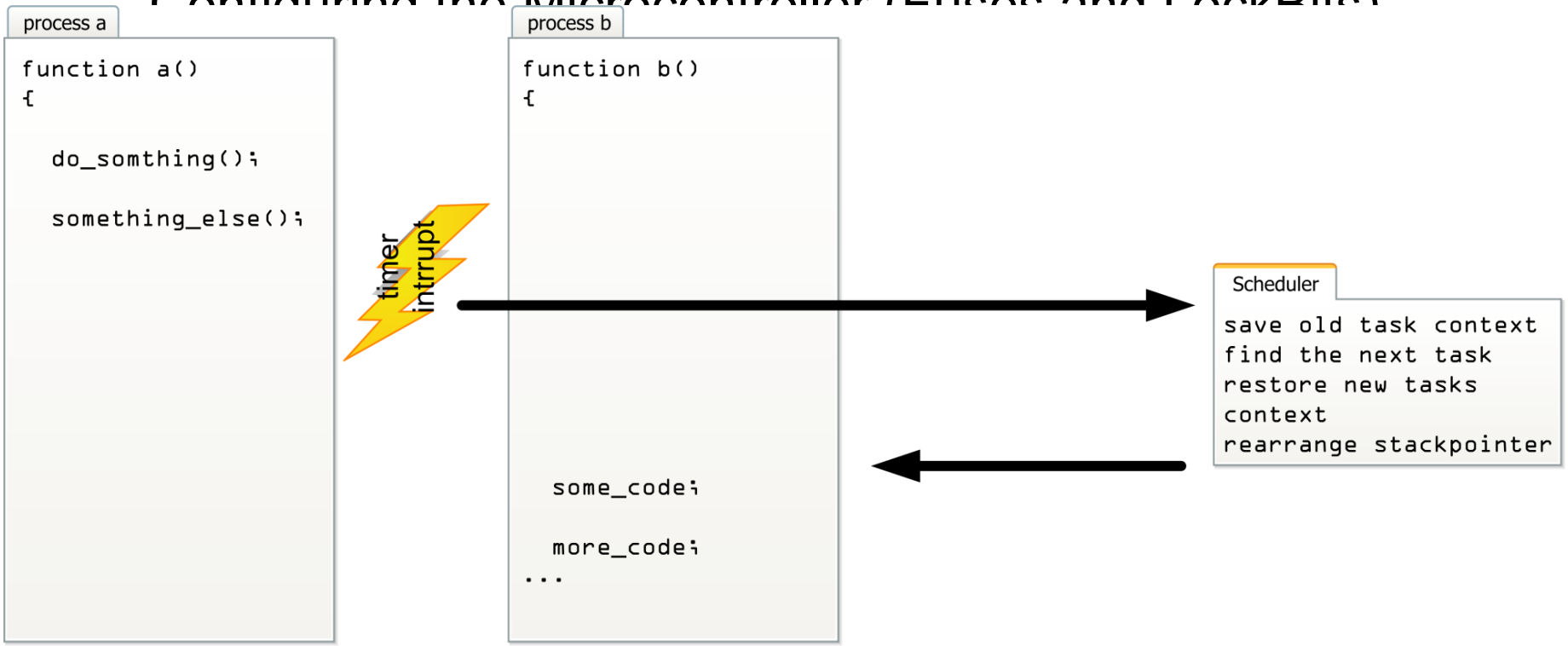
# Our Evaluation Board



# Topics

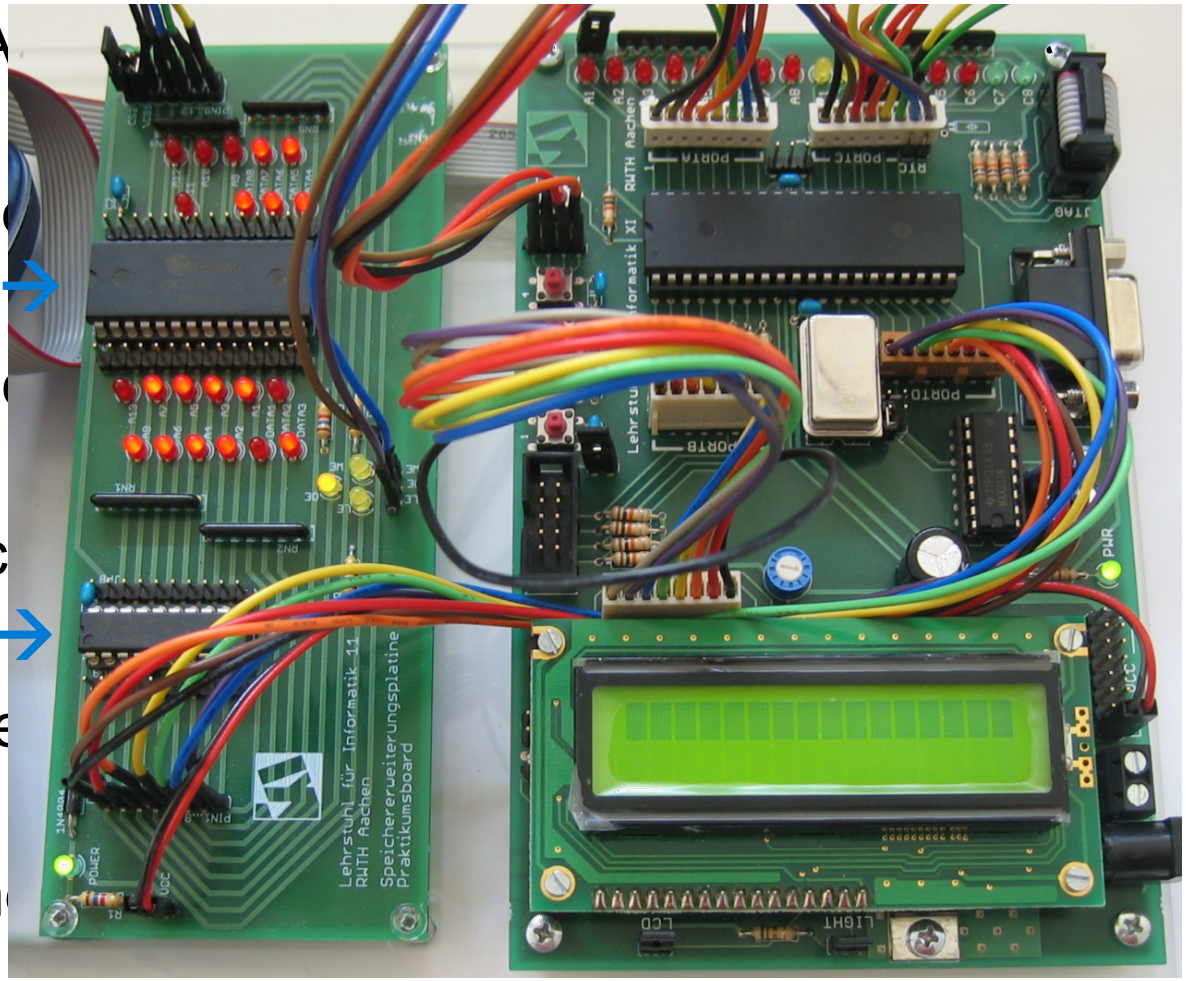
- Bootloader
  - Reprogramming new Programs through Serial Interface (RS232)
  - Configuring the Microcontroller (Fuses and LockBits)
  - Different Scheduling Strategies

## Command Flow during Scheduling



# Topics

- Memory Management
  - Dynamically A
  - Read-Write-D
  - **8 k Byte RAM →**
  - Access Restri
  - Different Alloc
  - **8 Bit Latch →**
  - Accessing Inte
  - External Mem



# Topics

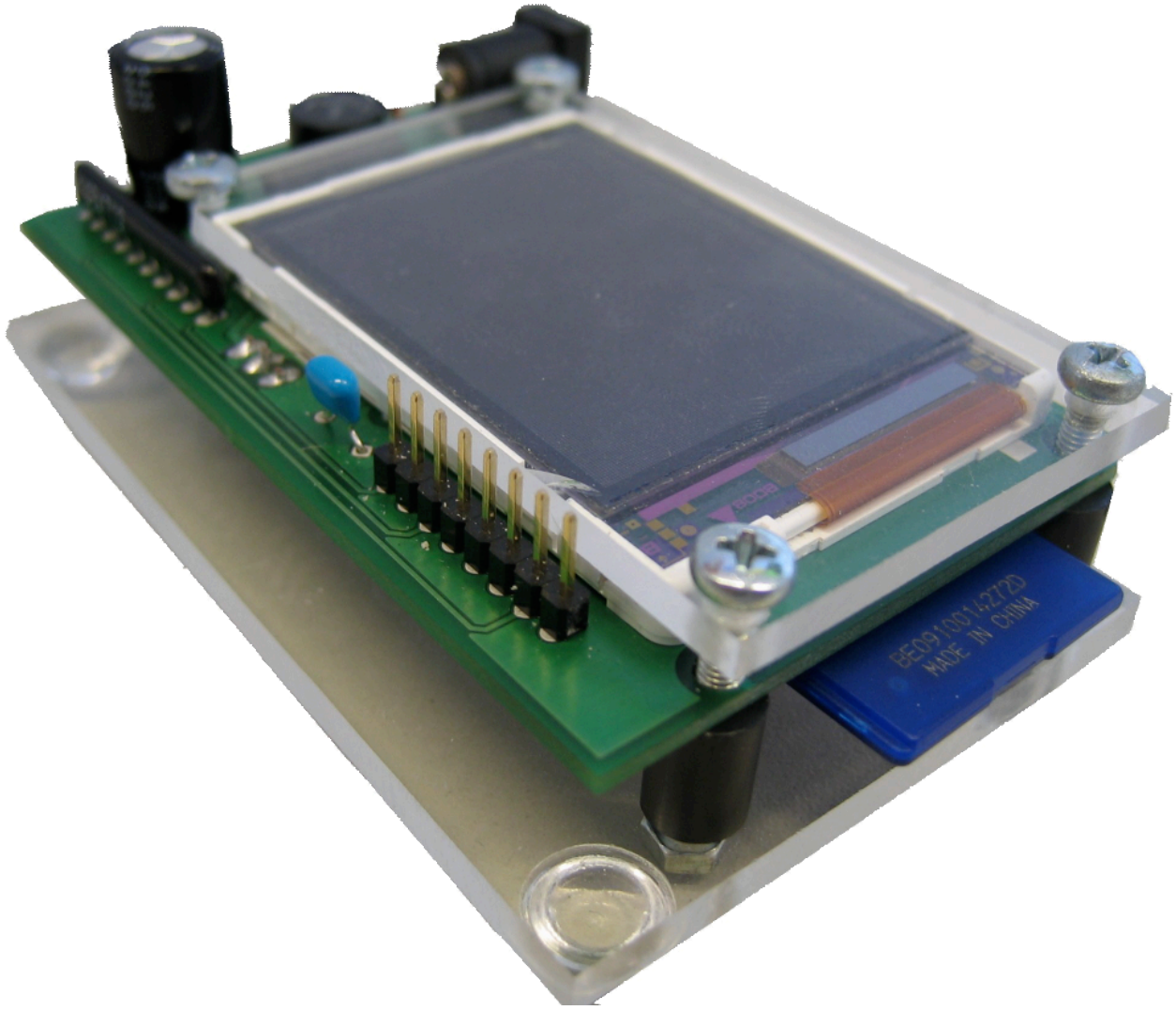
- Task Manager
  - User Interface to Previous Components
  - Start / Stop / Pause Different User Applications
  - Change Scheduling Priorities / Strategies
  - Change Memory Allocation Strategies

- Application Tasks (Last Experiment – Choice 1 out of 4)
  - Communication Between Two Microcontroller Boards
  - PS/2 Keyboard Driver + Simple Text-Based Game
  - RFID Reader + Access Control to Task Manager
  - Digital Picture Frame

# Application Tasks

- Communication
  - Serial Communication via UART
    - Different Format Settings
    - Handling Frame Format and Parity Errors
  - Serial Communication via Optical Interface
    - LED + Photo Resistor
    - Reading from ADC
    - Taking Care of Electrical Issues like Noise
- PS/2 Keyboard Driver
  - Using USART for Basic Electrical Communication
  - Handling different Keyboard Maps
  - Timing during Communication

# Application Tasks



# Experiences

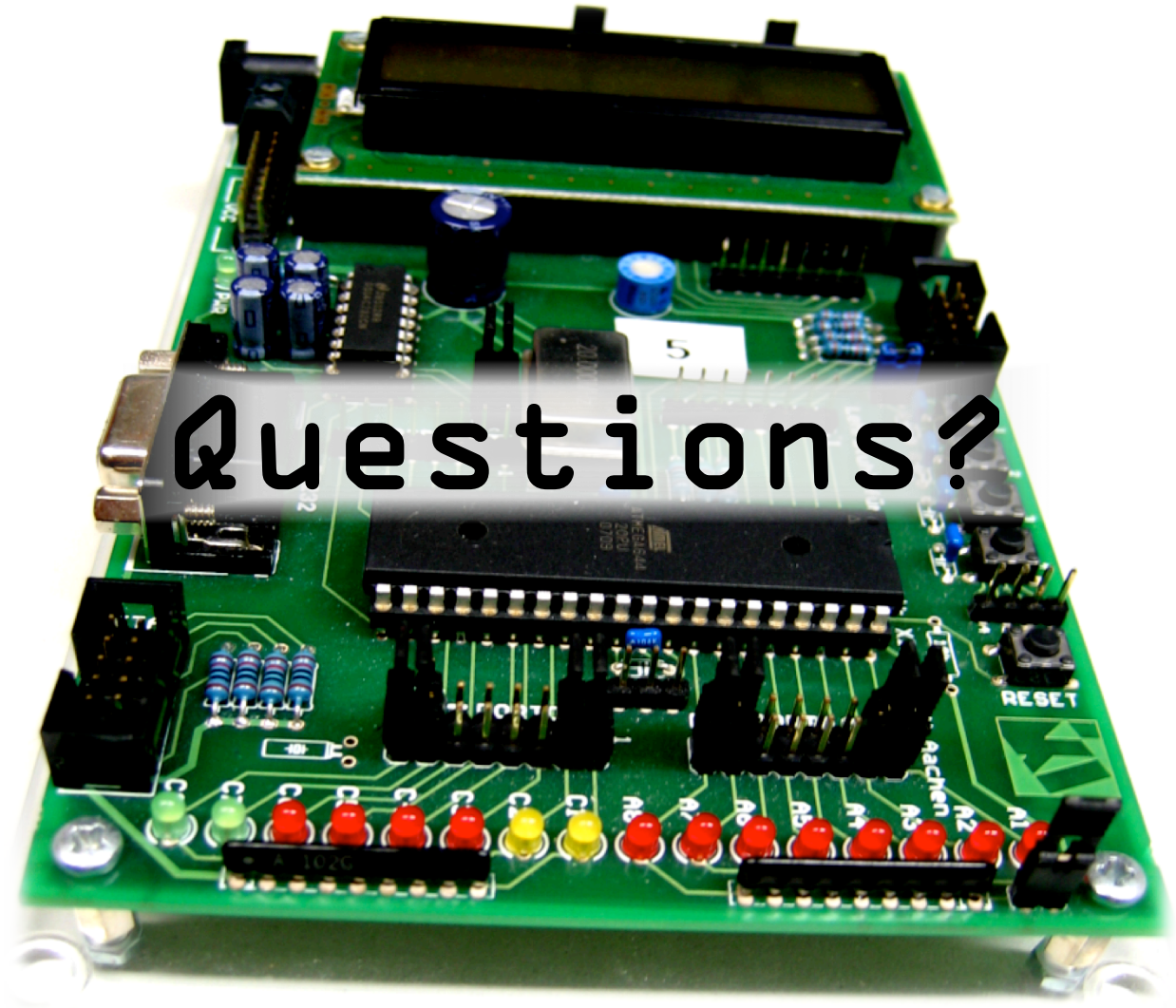
- Easy and Reliable Hardware is a very Basic Requirement
- Testing Environments are Needed for Preparation at Home
- Auxiliary Documentation → Everybody on the same Level
- Experiments' Documentation as Detailed as Possible
- Not to Restrict Students Creativity
- Biggest Challenge – Finding the Right Trade-Off

→ Resulting in Better Skilled and Motivated Students

# Conclusions and Outlook

- Covering Huge Amounts of Students
- Introducing Students to Embedded Hardware Programming
- Familiarizing Students with System Software Concepts
- Create more Testing Possibilities
- Evaluate the new Application Tasks

# Tanks for your attention

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# Details on the Evaluation Board

- Exchangeable Microcontroller (ATmega 16…ATmega 644)
- Exchangeable Crystal Oscillator (currently 20 MHz)
- All Ports (32 PINs) Lead Through to the Outside
- 2x16 Character LCD
- JTAG
- ISP
- RS232 Interface
- 4 Buttons
- 8 LEDs

# Resulted Curriculum

Extract of the BSc Curriculum in Computer Science at RWTH Aachen University

- 1st Semester
  - Lecture “Computer Engineering”
  - Lecture “Programming“
- 2nd Semester
  - Lab Course “Electrical Engineering“
  - Lecture “Data Structures and Algorithms”
- 3rd Semester
  - Lecture “Operating Systems and System Software“
  - **Lab Course “Hardware Programming“**

# Memory Arrangment