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FACULTY OF
COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME II

Session 6 - Environmental Systems: Management and Optimisation
Session 7 - New Methods and Technologies for Medicine and Biology
Session 8 - Embedded System Design and Application
Session 9 - Image Processing, Image Analysis and Computer Vision
Session 10 - Mobile Communications
Session 11 - Education in Computer Science and Automation

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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52nd Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
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V. Zöppig / O. Radler / M. Beier / N. Neumann / M. Fuchs / T. Ströhla

Modular smart systems for motion control teaching

Introduction

The main professional challenges for engineers in the drive technology are the complexity and heterogeneity of modern mechatronic systems. In order to prepare the future engineers for these tasks project based teaching methods are more and more included in the mechatronics curricula. In order to allow for the solving of high level problems it is crucial to provide a robust, easy-to-learn, and flexible hardware platform for the teaching of motion control and mechatronic system design, e.g. for robotics or mobile and autonomous systems.

The paper presents a modular system which is developed at the Mechatronics department at the TU Ilmenau in co-operation with the STZ Mechatronik Ilmenau.

Requirements on the modular teaching plattform

In order to support the main goals of the mechatronics teaching based on the design methodology proposed in the guideline VDI 2206 [1] it is necessary to fulfill the following requirements:

- Since the sensors and actuators of a mechatronic systems are application specific devices the system should concentrate on the signal and information treatment, power supply, and communication blocs.
- These modules must be usable / adaptable for a wide range of different actuators and sensors.
- The hardware modules and software tools should be available at low costs. This supports the creation of the enthusiasm to do “more then expected” during mechatronics projects or contests.
- Obviously, a certain robustness and fault tolerance is required.

The system should by scalable concerning the input/ output complexity as well as concerning the computing power for different application levels.

It is necessary to have a wide commitment to use such a system in different departments and faculties. The platform has to be integrated in the teaching flow. It means that base courses in the early phase of a mechatronics curriculum must provide the knowledge to use the system later.

Needed elements of a teaching plattform

A typical drive system for distributed architectures consists of the main parts:

- Power supply with EMC circuitry, voltage generation and buffering
- Communication interfaces e.g. field bus or Ethernet connection
- Controller device with peripherals and software
- Interface electronics for sensors e.g. ADC and amplifiers
- Interface electronics for the actuators e.g. power amplifier and safety circuitry

The sensors and actuators of such drive systems are application specific units in most cases. The signal conditioning for sensors and the power amplifiers for the actuators are also application specific or parameterized modules. The other parts of the system can be equal for many different applications (see **Figure 1**).

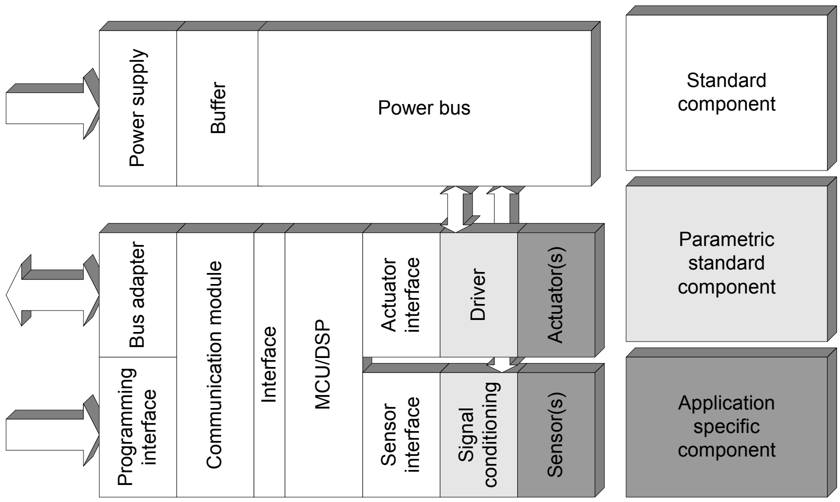

Figure 1 Networking drive general structure

In order to address a wide application field as well as different levels of complexity a modular system is the best choice. The modularity of the system has to be realized in different levels: schematics, functional hardware modules, simulation blocks and software routines. Since the sensors and actuators of a mechatronic systems are application specific devices the system (see **Figure 1**) may concentrate on the signal and information treatment, power supply, and communication blocs.

For all levels adequate software tools must be available. For this system the following tools are proposed:

Electronic design (schematics, layout, CAM processing):	CadSoft EAGLE, Version 4.16 for Windows [6]
Systems simulation, controller design	MatLab/SIMULINK [7]
Software development	CodeWarrior for 56800/E Digital Signal Controllers [8]

In addition, project examples and tutorials are provided as PowerPoint presentations.

The root: Match-X framework

The presented plattform bases in parts on the Match-X system. Since the MEMS technology opens a further miniaturization and integration potential for mechatronic drive components which is crucial for the system integration aspects. The European machine tool and plant construction industry is characterized by medium size company structures. Nonetheless there is also enormous cost and innovation pressure in this area. No costly development can be financed due to the small production numbers. One opportunity to solve the cost and production numbers problem while meeting their functional requirement is the modularization of MEMS on the basis of a modular framework.
A modular framework called “Match-X” for the implementation of modular microsystems aimed at the requirements of the machine tool and plant construction industry was proposed from the VDMA (German Machinery and Plant Manufacturers Association) in cooperation with German research institutions. Microsystem technology units (modules) are set up with standard packages and standard interfaces (electric, mechanical, fluidic and optical) [3]. These modules are capable of fulfilling specified tasks. Complete modular structured microsystems can be implemented by assembling these modules. The modules available so far were implemented in their majority as FR4- or LTCC TB-BGA (top bottom ball grid arrays, see **Figure 2**).

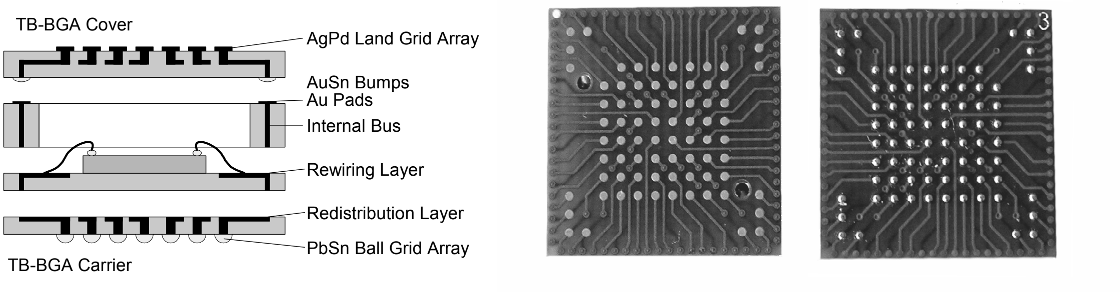

Figure 2 TB- BGA Package cross-section [2] and 17.5 mm FR4 module (land grid array left, ball grid array right)

Adaptions of the Match-X framework for teaching

Outgoing from this generalized network-ready drive system structure several multi-purpose modules were developed. These are a power supply module (5 V and 3.3 V), a controller module and a switch-mode power amplifier with current feedback. The new modules with a footprint of 12.5 to 12.5 mm² are realized in PCB technique with ball/land grid arrays on the top and bottom sides of the modules. In comparison with earlier presented modules with a footprint of 17.5 to 17.5 mm² realized in LTCC technique [4] considerable progresses are achieved in the field of volume and cost reduction. **Figure 3** shows the realized controller module with the Digital Signal Controller (MCU with 16 bit fixed point DSP core) MC56F8322 [5].

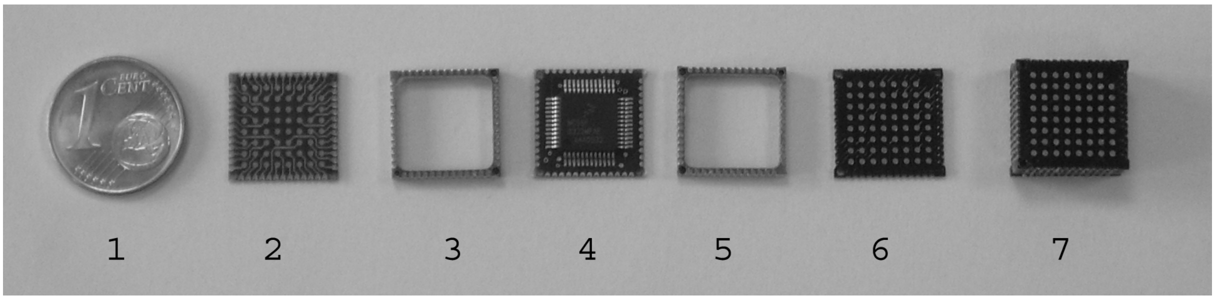

Figure 3 Controller module (1 … 7: scale, carrier, frame, controller PCB, frame, cover, and module)

For these controllers a powerful Integrated Development Environment (CodeWarrior Development Studio for Freescale 56800/E Hybrid Controllers) exists. Thus, an easy-to-learn link between the hardware modules and the software development is provided. This is especially supported by the integrated Processor Expert Tools (see [8] for details). The new modules are compatible to the commercially available didactic kit "efm-Kit" [9].

New hardware plattform

In order to provide a more robust platform for applications with lower miniaturization needs, a new concept is under development. This new systems uses similar schematics and ensures the reuse of software modules in Match-X systems.

This system defines three levels of components: main computing unit, distributed computing unit, and actuator-sensor modules. By combining these units, distributed mechatronic systems can be implemented. Networking is achieved by CAN bus (see **Figure 4**).

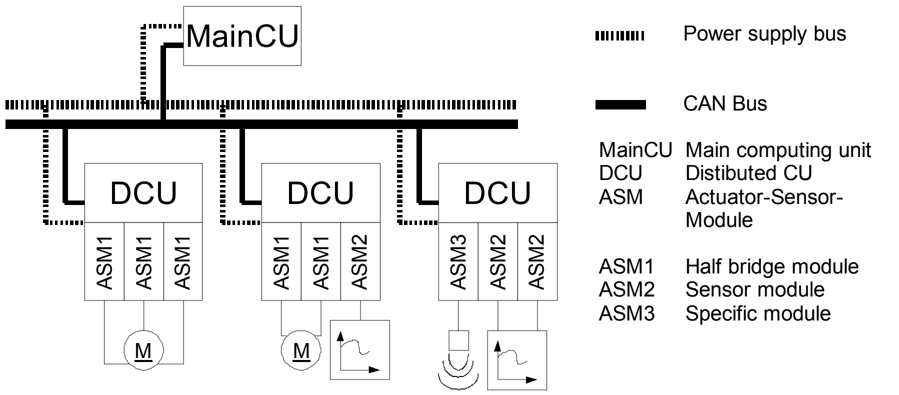

Figure 4 Distributed mechatronic system outline

All standard components (refer to **Figure 1**) are integrated on one PCB (100 x 100 mm² footprint). This board can be equipped with piggy-bag actuator-sensor-modules. The individual actuators or sensors are connected to these modules (Figure 5).

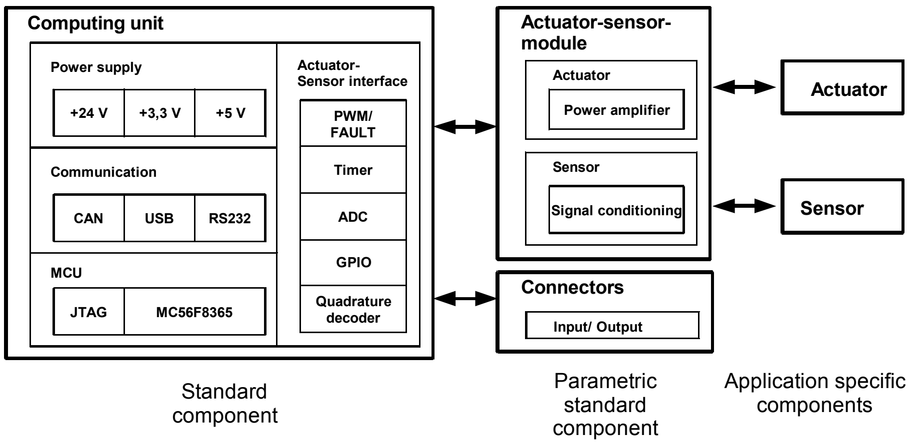

Figure 5 Distributed computing unit block schema

In order to allow the networking by CAN bus a special CAN communication protocol was implemented. It allows the networking of up to 8 nodes. Up to 64 global 16-bit variables of the individual nodes can be influenced (read, write) over the bus. An additional master device allows the visualization and the control of the network over an USB interface. This master device also runs communication state machines for the individual nodes. The defined states are NOT_INITIALIZED, BOOT_UP_RECEIVED, COMMUNICATION_STARTED, COMMUNICATION_STOPPED, BYE_RECEIVED, and ERROR_RECEIVED. A step-by step instruction exists for the adding of this protocol to a software project.

Plattform use

The platform is in use for different teaching purposes. A so called Rotating Leg Vehicle (RoLV) consists of 6 networking DC-motor drives, which control the individual wheel position and velocity (see **Figure 6**).

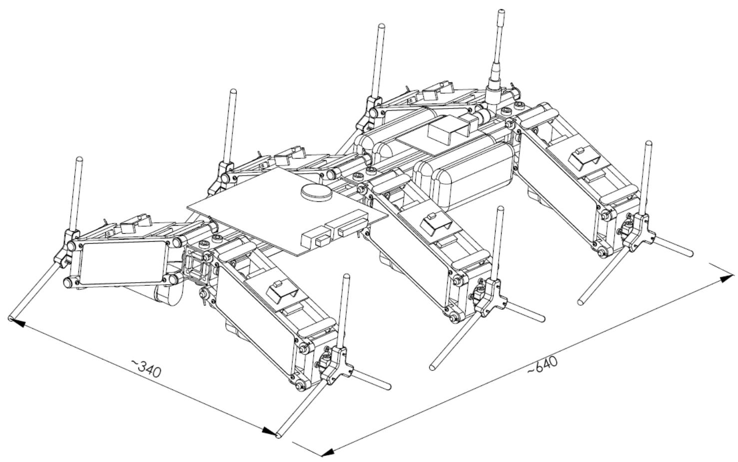

Figure 6 CAD of the TU Ilmenau Rotating Leg Vehicle [10]

Another usage is the DC motor practical training (including state control) at the Mechatronics department of TU Ilmenau (see **Figure 7**).

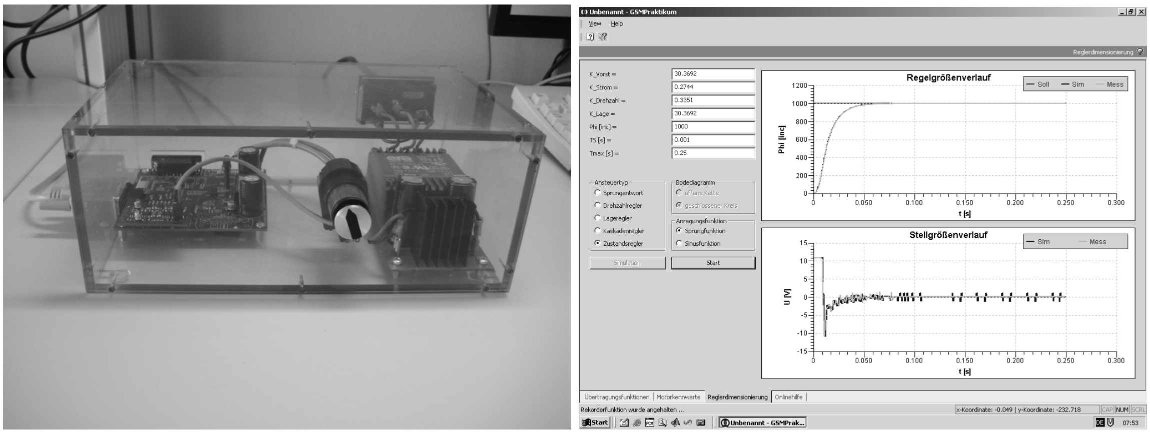

Figure 7 DC motor practical training (left: set-up, right: GUI screenshot)

The platform is subject of further development. This is influenced by the applications.

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