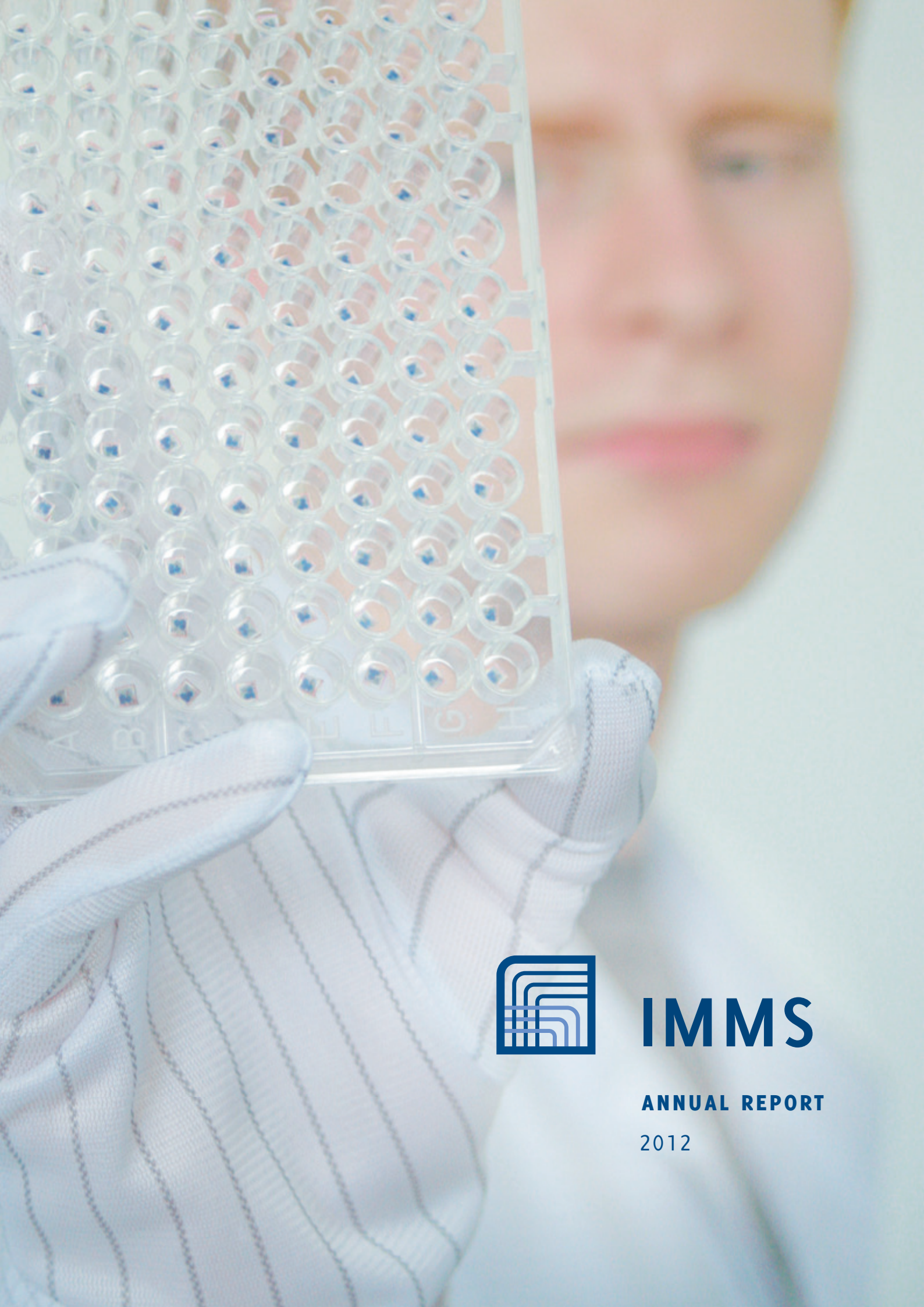


# IMMS

## ANNUAL REPORT

2012

# Publishing Details


**Publisher**
Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH*

Ehrenbergstraße 27
D-98693 Ilmenau

+49.3677.6955.00 *Tel*
+49.3677.6955.15 *Fax*
imms@imms.de
http://www.imms.de

**Editing and Proof Reading**
Prof. Dr.-Ing. Ralf Sommer
Dipl.-Ing. Hans-Joachim Kelm
Dipl.-Hdl. Dipl.-Des. Beate Hövelmans

**Translation**
Susan Kubitz, www.QualityTranslations.de

**Design, Photographs and Illustrations**
Dipl.-Hdl. Dipl.-Des. Beate Hövelmans

**Typography and Information Graphics**
Dipl.-Hdl. Dipl.-Des. Beate Hövelmans
Danielle Warnecke, B.A.

**Printed by**
Brandtdruck e.K., www.brandtdruck.de





Editorial deadline: 26. April 2013


**Frontispiece:**

RFID microsensors in this type of microwell plate will make the biological analysis of the future more efficient. IMMS is applying this equipment in a prototype form to find multi-modal energy-autonomous microsensor solutions in the "GreenSense" research programme (see also p. 21). Photograph: IMMS.

* Institute for Microelectronic and Mechatronic Systems not-for-profit GmbH



IMMS

# Contents



**Abbreviations**

**ADC** *Analog-to-digital-converter*
**APU** *Audio processing unit*
**ARM** *Advanced RISC Machines*
**ASIC** *Application-specific integrated circuit*
**BA** *Berufsakademie (University of Co-operative Education)*
**BMBF** *Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)*
**CMOS** *Complementary metal-oxide-semiconductor*
**CPS** *Cyber-physical systems*
**DFG** *Deutsche Forschungsgemeinschaft (German Research Foundation)*
**EDA** *Electronic design automation*
**EMC** *Electromagnetic compatibility*
**FPGA** *Field Programmable Gate Array*
**IC** *Integrated Circuit*
**ICT** *Information and communications technology*
**IEEE** *Institute of Electrical and Electronics Engineers*
**InES** *Intelligent electronic systems for toolbuilding, plant and medical engineering; call for proposal of the German BMBF)*
**KNX** *worldwide standard for all applications in home and building control*
**LIN** *Local interconnect network*
**MEMS** *microelectromechanical systems*
**PCI** *Peripheral component interconnect*
**PXI** *PCI eXtensions for instrumentation*
**RF** *Radio Frequency*
**RFID** *Radio-frequency identification*
**RGB-LED** *light-emitting diode (red/green/blue emitter)*
**SMACD** *International Conference on Synthesis, Modeling, Analysis and Simulation Methods and Applications to Circuit Design*
**SME** *Micro, small and medium-sized enterprises*
**TU** *University of technology*
**UVM** *Universal verification methodology*
**wM-Bus** *Wireless meter-bus for the collection of consumtion data*
**ZigBee** *Industry standard for wireless networks*

# Foreword

Professor Ralf Sommer (l.) and Mr. Hans-Joachim Kelm at the film session organised by STIFT Thüringen in connection with IMMS' nomination for the Thüringen Innovation Prize 2012. © STIFT, Photograph: audiovisual elements.

The **strategic core** of IMMS' work is applied research. The Institute's full name, Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH (Institute for Microelectronic and Mechatronic Systems not-for-profit GmbH), devotes itself to the creation of software and systems that culminate in the development of actual products. It does not stop at achievement of research outcomes, it always takes them further, distributing them and turning them into practice. In doing so, it maintains close cooperation both with Ilmenau University of Technology and with industrial partners. IMMS' contribution is the applicationorientated preliminary research into and further development of microelectronics, systems engineering and mechatronics solutions.

The Institute's research strategy came into sharper focus in 2012 and IMMS was given an even sounder footing by involvement in further relevant projects. They involved interdisciplinary and collaborative endeavours which have continued steadily to add to the synergy effects between the fields IMMS covers. The knowledge and experience gathered this way are being systematically expanded. Theory and practice are bound together. This principle is the strong foundation for the fulfilment of the Institute's task, both now and – even more – in future. In all its activities IMMS' strategy is in line with the Federal German Government's policy demanding overall system competence within the national High-tech Strategy. IMMS is thus committed to involvement with plant and equipment manufacture and medical technology, in order to strengthen the value-added supply chain by offering a service that starts with system design for intelligent electronics, integrates the system designed and ends with the final testing. This service receives some financial support within the InES guidelines of the Federal Ministry of Education and Research (BMBF): among the Institute's tasks are the development of new methods and products. It is consolidating and extending its network of strategic partnership between science and industry. The industrial spheres with growth potential in industry are largely – as far as Germany is concerned – cars, mobility, machinery, automation, health, medical technology, logistics, ecology, energy and the service sector. It is only on a foundation of information and communications technology (ICT) that innovation in these fields will be achievable. IMMS is fully involved in the German ICT2020 programme, extending its systems competence while opening it up also to its partners, especially the SMEs of Thüringen. This national participation enables IMMS to match its aims very closely to those of Thüringen's policies for industry and academia. An instance of the Institute's important contributions is vital research into "green" production methods and resource consumption, closely matching the "Land" of Thüringen's GreenTech policy, which applies to energy efficiency and effective use of resources and materials.

The vast knowhow that has accumulated in IMMS can be applied to a wide variety of fields, such as pollution monitoring, green building, green mobility and emergency management. Work goes on all the while at IMMS to create new hardware and software solutions in all these fields – solutions which go by the name of multimodal sensor systems and save both money and energy. A major project launched in 2012, "GreenSense", is serving to infuse these subjects with new energy.

Turning from research strategy to **partnerships**, there are again particular foci. The uses of IMMS' services and its working partners are found in industry, in the national and international research scene and in Ilmenau University of Technology. For example, with other collaborators of the TU, IMMS staff are researching the design and use of MEMS (microelectromechanical systems) in multiphysical systems such as those represented by the RF applications being investigated for the DFG (German research foundation) "MUSIK" project, started in 2012. The partners in another case, that of a magnetic levitation positioning system, are the TU and an industrial company, PI (Physik Instrumente). This direct drive enables a load on a freely swaying stage to be moved around in 6 dimensions to an accuracy of mere nanometres. The Institute was nominated for the Thüringen Innovation Prize 2012 because of this work. Another project in which IMMS is in close collaboration with the TU is "3DNeuroN", a new 3-dimensional low-power, low-noise sensor/actor electrode array, which is intended for future use in the measurement and simulation of neuronal activity to support better healing of damaged nerve tissue. The work on the "GreenSense" project already mentioned is currently focussed on R&D (jointly with Ilmenau University of Technology) to create a modular techno-logical platform enabling highly complex, dense, self-powered multimodal smart sensor networks to be efficiently constructed and operated.

IMMS takes very seriously its duty of **encouraging the scientists of the future**. In 2012, it supported the Ilmenau TU and other universities in Germany and abroad by supervising BSc, MSc and PhD dissertations, in providing internships and in employing students as part-time research assistants. For design support and the lab equipment for electronic and mechatronic systems, the Institute has its own internationally competitive infrastructure available to draw on for its research work and the preliminary qualification processes. This is one reason why highly motivated, high-flying students find their way to IMMS, to our great pleasure. Another way in which the Institute supports and stimulates new academic blood is the Scientific Seminar, at which undergraduate and doctoral students present their work and any issues for discussion. The intense academic disputation initiated in this way overflows subject borders and encourages new connections to be made, new ideas to be considered and academic method to be espoused in the pursuit of knowledge.

Turning to **projects**, a considerable number of these have been progressed by the 91 staff at IMMS together with innovative ideas of their own, to get new products to the marketable stage for industry. One development in which the Institute is involved is a means of greatly improving the thermodynamic efficiency of gas-fired power stations and combustion engines so that they become more energy-efficient. The staff has also made a vital contribution to the market viability of interference-free satellite navigation systems that will enable unmanned aerial vehicles to be used in safety-critical situations. IMMS has produced a crucial component for the next generation of terahertz scanners to permit people to be searched for hidden dangerous objects as they simply pass by. Systems solutions produced by IMMS researchers are contributing to the improvement of energy efficiency in buildings by means of acoustic monitoring and to the creation of flats and apartments in the near future that are suitable to people of any age, economical in their use of energy and connected online to the outside world. This annual report will throw light on all the work which has gone into these and other research developments at the Institute in 2012.

The IMMS team would like to express its appreciation of the funding from the "Land" of Thüringen that makes input from IMMS possible as a means of helping Thüringen SMEs. **Our thanks go to** the Board of Directors and the Scientific Advisory Board of IMMS for their constant encouragement, advice and support. We should also like to extend our thanks for the outstanding cooperation we receive from the Heads of Departments and Professors of Ilmenau University of Technology. All the varied collaboration that takes place is not merely a great enrichment of our efforts but achieves synergy effects which grow from the interdisciplinary connections between the research fields of both establishments. Our thanks also go to our business partners, supporters and friends and to all the people who encourage us in our efforts. At IMMS, however, it is our creative and committed thinkers who are at the very core. It is these staff and students whom we should particularly like to thank for contributing their expertise, individual skills and knowledge so constructively and reliably to the IMMS team and for involving themselves in our shared future.

Dipl.-Ing. Hans-Joachim Kelm

Prof. Dr.-Ing. Ralf Sommer

# Industry 4.0 – Germany's strategy for the future:
## the challenges to science and industry

### IMMS helping to progress Industry 4.0

Part of the Federal German government's economic policy is the High-Tech Strategy 2020. Within it, the forward-looking Industry 4.0 project launched in October 2012 has an ambitious aim: Already a supplier and user of innovative industrial production technology, Germany is set to become a market leader, for instance in the field of CPS, cyber-physical production systems. In 2012, IMMS joined Silicon Saxony e.V. in launching a new CPS work group in Dresden as a means of furthering the new Industry 4.0 strategy. Uwe Gäbler of Infineon Technologies Dresden and Wolfang Sinn of IMMS are to head a centre of excellence for this new technology, which will shape future markets, drawing together the work of representatives from research and science. The centre will also support cooperation between science and industry by interdisciplinary collaboration and cross-industry programmes. Without such activity it will not be possible to meet the challenges inherent in this forward-looking project.

IMMS has already, in earlier research projects, contributed initial work on subjects relevant to the success of Industry 4.0 and incorporates the knowledge obtained into its current approaches. "GreenSense", the interdisciplinary research project launched in 2012, sees the Institute pursuing the goal of developing modular technology platform for energy-autonomous smart sensor networks. Such networks will make a wide variety of new applications feasible, particularly the monitoring and control of future production, transport and operating processes. As a result, they will be far more efficient in their consumption of energy and other resources.

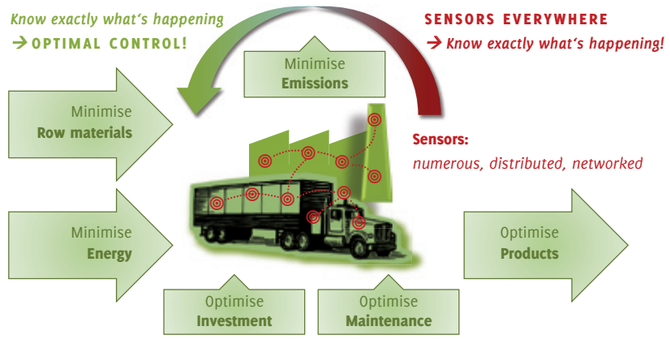
"MEMS2015" is another project which was launched in 2012 and in which IMMS is a partner. It is intended to bridge the current disparities between chip and sensor manufacturing methods and to fill gaps in the integration process for chip and sensor, achieving innovative products. One result will be better sight and touch for autonomous systems like assisted-living robots. It is also hoped that the design of MEMS will in future be a possibility for SMEs themselves thanks to the new methods, so that they can manufacture their products much more efficiently.

### Challenges for Industry 4.0

The CPSs which are the focus of the work group in question have been defined in the context of Industry 4.0, one of the forward-looking projects contained in the Federal German High-Tech strategy, as one of the most essential technological steps to a fourth industrial revolution. Already, embedded computer systems are controlling the functions of vehicles, machines and equipment of every kind. CPSs are the new generation of such systems. They constitute the foundation for the Internet of Things and Services, the name given to the future means of linking real world situations to the Internet of the future. The effect will be that everything communicates with everything else. The need now is for new dimensions to be opened up enabling the environment to be registered through the Internet and systems to act and interact autonomously by virtue of their increased cognitive ability. It will be vital to use smart controls for the processes with their increasing speed and complexity. CPSs will thus contain a huge number of sensors and chips, will be networked throughout and will have a vastly extended range of performance, not only acquiring information in the form of data, but also monitoring, analysing and modelling it, then communicating independently. Thus they will render industrial processes automatically and highly efficient by providing the self-regulating controls and smart optimisation.

Industry 4.0 stands for a basic paradigm change: no longer centralised, but now decentralised controls. High flexibility with customised, digitally refined products and services are the aim. The old boundaries between industrial branches will disappear. New borderless fields of activity and forms of cooperation will arise. Value added chains will change, division of labour will be reorganised.

The foundation of Industry 4.0 will be CPSs and smart technical systems (Fig. 2). CPSs will regulate things in the real world from the Cloud, recording data from sensors and detectors and using it to regulate and optimise the flow of information, energy, goods and human and material resources. To do so, they will require for a vast number of chips with new properties and platforms on which hardware and software with fullest security and highest quality can be based.




Vision of the "GreenSense" project: Monitoring and controlling of processes in transport and industry and on the shop floor using smart sensor networks – to conserve resources and raise energy efficiency. Diagram: IMMS.

*"It is only a question of time before platforms are made for CPSs and around these platforms software and hardware ecosystems are established. These ecosystems will be supply chains and market places."* [1]

As one of the consequences there will be many new challenges for the sensor systems to meet in order to cope with the complexity. The sensors will require development into environmental recognition systems with the following properties:

- Physical situational awareness (sensor fusion, virtual sensors, pattern recognition, situation maps),
- Anticipatory autonomous action (estimation of consequences),
- Cooperation and behaviour (multiagent systems, group behaviour, shared control),
- Human-machine interaction (rules for interaction),
- Machine learning (CPSs adapt to their user or the situation),
- Strategy of self-organisation and adaptation (self-organisation in the production process, whereby the workpiece itself becomes a source of information and dictates the sequence).

### Future prospects

Sensors and actuators are classic components of microsystems technology and form the basis of a wide range of applications in electronics, mechanics, optics, biology and chemistry. The modern microsystems used in these fields are already networked, autonomous, smart – far more than a mere component. They have become independent nodes in smart systems, for instance sensor networks. Miniaturisation as it progresses is constantly opening up new fields of application en route to the intelligent environment. Science and industry must meet the further challenge of bridging the gap between nanotechnology and the micro and macro environment. In this challenge is the chance to target the effects of nanotechnology and make them available within the desired microstructures, which will represent a huge gain in functionality as against the present applications for nanotechnology.

These are goals being pursued by IMMS in the Nano Goes Macro consortium. The initial consortium first saw the light of day at the micro-nano-integration innovation forum organised in 2010 by Ilmenau University of Technology. Nano Goes Macro, a scheme to unite SMEs and research establishments from Thüringen and other federal states of Germany, aims to make micro and nanotechnology usable by SMEs. The last two years have seen the scheme developing ideas on the investigation and development of new products (using these innovative multisensory systems) for a great variety of markets on the basis of shared technology platforms. IMMS has worked out a concept in conjunction with nine other consortium partners and submitted it to the Federal Ministry of Education and Research (BMBF) so that Nano Goes Macro may be included in the national Twenty20 – Partnership for Innovation programme. The plan is for IMMS to develop an electronics platform jointly with the other partners which will achieve data acquisition and processing and union of the sensor systems into a network. The Institute is also hoping to share in the creation of machines and equipment into which such sensors will in future be installed and to help develop a platform for the manufacturing of the sensor systems.

**Contact:**
Dr.-Ing. Wolfgang Sinn
Business Development Manager
wolfgang.sinn@imms.de

**Source:**
1 CPS (2010); Professor U. Aßmann, Professor M. Wacker.

# IMMS' partnership with Ilmenau University of Technology

## Joint research projects

IMMS as an affiliated institute of the University is not the only one to benefit from the networks and research of the other partner. The TU Departments with which IMMS co-operated actively in 2012 were 28 in number, from the broad fields of electrical and mechanical engineering, computer science and engineering, automation, mathematics, media and communications and the academic subjects addressed included high-precision positioning and measuring machines, biomedical technology, sensors for monitoring of high-temperature processes, and RF frequency technology for satellite-aided navigation. In parallel, the Institute operates in a close industrial network, in the form both of industrial clusters and of regional and national innovatory networks. These fields include automotive engineering, microtechnology, microelectronics and optics. Valuable impetus is given by the groupings. They are the chance to pool skills, use partners' technology and develop joint marketing strategies.

### IMMS nominated for the Thüringen Innovation Prize

IMMS maglev direct drive brought it to nomination for the 2012 Thüringen Innovation Prize. In the "Industry and Materials" category; the institute made it to the "best three" podium. The drive is a positioning system completely controlled by magnets and it will position the load very precisely in six coordinates, making use of the principle behind maglev trains. IMMS developed the engineering basics in association with PI (Physik Instrumente) of Karlsruhe and Ilmenau University of Technology. It will enable industry to manufacture products of the future on a molecular scale in vacuum, an option much needed in the case of microchips and in the life science and biomedical engineering sectors.

### Collaborative Research Centre No. 622, "Nano Positioning and Measuring Machines" (NPMs)

IMMS has long been involved with the TU in research on this Collaborative Research Centre of German Research Foundation (DFG), No 622, which celebrated its first 10 years of work in the design and creation of NPM machines with their extreme precision in May 2012. IMMS' current work is on the development of a new-type precision drive to enable the stages not only to be moved through distances accurate on the nanometre scale but despite large dimensions and mass, which occasion long distances of travel, to have the stability of position maintained.

### "GreenSense" project for greater energy efficiency

The "GreenSense" project begun in July sees IMMS doing R&D on a modular technological platform in association with the ZMN (Centre for Micro- and Nanotechnology) and the RF and Microwave Research Laboratory at the University. The platform is to enable highly complex, close-knit, self-powered multimodal smart sensor networks to be efficiently constructed and operated. The sensor networks will open up a wide range of applications, particularly in the monitoring and control of industrial production, transport and operational processes, so that those processes become more energy-efficient and less resource-intensive. Energy harvesting solutions have already be designed in the project to permit the wireless sensors to be operated on a self-powered basis.

### "MUSIK" project for innovative design of microelectromechanical systems

In the context of the new DFG project named "MUSIK", IMMS and researchers from Ilmenau University of Technology are researching the amplifying, controlling, oscillating and switching properties of MEMS (microelectromechanical systems) in order to design MEMS in conjunction with the electronics for radio frequency circuits and systems. The aim is to achieve a universally applicable design method which will remove the technological discrepancy which currently exists between conventional MEMS design methods and those for circuit design which are model-based and computer-aided and are used for ASICs (application-specific integrated circuits). The hope is to reduce development time by up to 30%, speeding up market entry because of the innovative methods and less frequently necessary redesigns.

### "3DNeuroN" project: Mimicking the brain

Since 2012 the IMMS has been carrying out research on a novel 3-dimensional low-power, low-noise sensor and actuator electrode array for measuring neuronal activity and stimulating nerve cells. The Institute has been working in close cooperation with the Institute of Biomedical Engineering and Informatics and Centre for Micro- and Nanotechnologies at the Ilmenau University of Technology as well as the University of Tampere, Finland. A 3D array consisting of 800 to 1000 electrodes is to be developed in this project in order to have neurons arbitrarily stimulated and their response recorded in three dimensions.

### "KOMPASSION" – A compact adaptive terminal antenna for interference-free satellite navigation

In the "KOMPASSION" project, IMMS is working with the German Aerospace Centre, RWTH Aachen and Ilmenau University of Technology on new designs, technology and algorithms to make the adaptive group antennas needed for satnav interference mitigation more compact. Antennas of this type fulfil the high requirement for interference robustness which is necessary, for instance, in safety-critical situations where unmanned aerial vehicles are used. They have, however, been too large and heavy to date for use in small robots or mobile devices. The aim of the project is a receiving unit which is only half as big as a conventional group antenna but has the same number of individual elements and demonstrates the applicability of the signal treatment developed.

## Joint encouragement of young academics

IMMS researchers, in 2012 as in previous years, played a full part in encouraging the next generation of scientists. They pass on to students at Ilmenau University of Technology knowledge of methodology soundly based in theory and link this at an early stage to its practical use. The Institute also offers training courses and guided tours of the establishment. In all, the year 2012 saw 22 students working at IMMS either as interns or student research assistants or in association with the dissertations they were preparing for their BSc, MSc or German "Diplom". The fact that the Institute networks so closely with industry provides the new generation of scientists with the opportunity to work on subjects of practical relevance where the results really matter.

### IMMS and Ilmenau University of Technology win SMACD competition

SMACD stands for the subject of the International Conference on Synthesis, Modeling, Analysis and Simulation Methods and Applications to Circuit Design which was held in Seville in 2012 and ran a prestigious competition for doctoral and Master's students. It was won by the IMMS scientiest Muralikrishna Sathyamurthy and Felix Neumann of the Ilmenau TU for their presentation on the subject of UVM-based Verification of Smart-Sensor Systems. The prize was given for their verification procedure for mixed-signal circuits, in which real application scenarios and error constellations can be simulated on a computer. There were nine finalists for the winners to beat.

### Events organised by IMMS and Ilmenau University of Technology

As a teacher, Professor Sommer is involved not only in the AG Lehre (working party on teaching) but also, together with IMMS, in the Basic Engineering School that Ilmenau University of Technology has now established. The School is intended to make engineering degrees more attractive to potential students, particularly by using new methods of teaching and learning. The bottom line will, it is hoped, be a reduction in the engineering student drop-out rate because of better-anchored knowledge and raised motivation. IMMS is both trainer and motivator, offering not only highly practical and relevant placements but illuminating guided tours.

There is a yet younger generation receiving the attention of IMMS and the University. When 1300 children, aged 8 to 12, came to two lectures during Ilmenau's Children's University, IMMS gave them a practical demonstration of how sounds – particularly voices – can be radically altered.

Maglev direct drive with passive stage and no wiring. Photograph: IMMS.

# IMMS nominated for Thüringen's 2012 Innovation Prize for magnetic levitation direct drive

Having been nominated for the Thüringen Innovation Prize in 2012, IMMS was among the top three competitors in the "Industry and Materials" category. The direct drive is a positioning system completely controlled by magnetism and permitting a load to be swayed accurately through six coordinates. The IMMS scientists have developed the prototype together with PI (Physik Instrumente), Karlsruhe and Ilmenau University of Technology. The researchers are employing the same principle as does the maglev train. They have developed the basic engineering principle so that industry will be able to manufacture products of the future on a molecular scale in a vacuum. This is necessary, for example, in the production of microchips or for certain processes in materials research, surface measurement technology, the life sciences and the biotech sector.

The distances of travel for the direct drive stage are 100 mm x 100 mm x 0.15 mm. It can move freely within this space in 6 dimensions – the three spatial axes and the rotation around each of them. The stage levitates, supported only by a magnetic field which serves as drive and guidance for all the axes and is generated by only six planar solenoids. The stage is thus entirely cable-free and functions without any form of contact, with the consequence that it will work in absolutely clean environments almost without generating any contaminant particles at all. The drive achieves highly precise movement: deviation from the ideal is never more than 10 nm.

The positioning of the stage within the 6 degrees of freedom is modified by a new type of sensor head made up of optical and capacitive detectors. Conventional sensors have to date worked on the laser interferometry principle, acquiring position data from three laser sensors distributed around the platform but the sensor head of the new drive is integrated into the stator and is much more compact.

Dr. Christoph Schäffel, Head of Mechatronics at IMMS, receives the nomination certificate at the award ceremony for the Thüringen Innovation Prize on 27/11/2012. Photograph: IMMS.

Steffen Arnold, Market and Products Manager, PI (Physik Instrumente), Karlsruhe Photograph: PI.

## Steffen Arnold, Physik Instrumente

"IMMS has infused our development of a magnetic levitation direct drive with significant impetus. This is the type of technology which will have to be used in future for manufacture that involves accuracy down to the nanometre scale and absolute freedom from dust particles of any kind in the semiconductor, life science and biotech sectors.

As the industrial partner of IMMS we are particularly delighted that the Institute's work on the drive was nominated for Thüringen's Innovation Prize in 2012. The new concepts applied – the new six-dimensioned maglev drive, the integrated 6D sensor and the highly accurate steering algorithm – will underpin future customised product development. Our scientists have moved forward in the company of their IMMS colleagues into magnetic drive territory where there are prospects of hitherto unattainable accuracy of positioning, whether on a plane or in 6 dimensions. IMMS has such expertise in the field of magnetic drives that it is the ideal partner for our work on this development. We are looking forward greatly to continued shared successes in the field."


Professor Burkhard Utecht, Director of Thüringen's University of Co-operative Education (Staatliche Studienakademie Thüringen – with campuses in Eisenach and Gera). Photograph: IMMS.

### Prof. Dr. Burkhard Utecht, BA Eisenach

"Students at our University follow a three year dual BSc course, taking the theoretical part at the Berufsakadamie (Thüringen's University of Co-operative Education) in Eisenach and the practical part in companies which offer us regular placements.

For more than three years so far, the students have had the benefit of all of the knowledge transferred to them in the lectures of teacher-trainers at IMMS and in the supervision they receive at IMMS for BSc dissertations (on smart sensors and intelligent systems, to give two examples). The cooperation agreement that we concluded with IMMS in 2012 has enabled other IMMS teacher-trainers to enrich our curriculum by teaching on current research and development concerns in automation and microcontroller programming. The teaching includes demonstration of design method for automation equipment using scenarios and model-based design, which is one of IMMS' research fields. In order to maintain and even raise the academic level we offer, the Berufsakademie seeks constantly to provide students with the stimulus of the state of the art in their subjects. It is for this reason that we are so pleased to intensify our joint work with IMMS. The company is making a vital contribution to the professionalisation of the training we give."

Lutz Langelueddecke, Development Manger, Melexis GmbH. Photograph: IMMS.

### Lutz Langelueddecke, Melexis GmbH

"Last year, IMMS modelled and verified a mixed-signal IC with a controller for Melexis. The work was of assistance in the manufacture of a monolithic Slave-IC to drive LIN RGB light emitting diodes, which give cost savings in the ambient lighting for vehicle interiors. The Institute's highly competent staff supported us in the creation of testbenches for top level verification. We were able to benefit directly from the experience gained by IMMS from the 'Thermulab' project and made use of the knowledge acquired on mixed-signal simulation of embedded software. The Institute used modern mixed-signal behaviour description language for the modelling, which will enable us to transfer the results from the mixed-signal ICs in question across to future developments, improving design efficiency. The IMMS staff came and worked as colleagues in the Melexis project team, responding to any changes with great flexibility. Their high technical competence confirmed once more how well and enjoyably we have been able to collaborate with IMMS over recent years. We will welcome the opportunity of further joint projects."



### Univ.-Prof. Dr.-Ing. habil. Martin Hoffmann, Ilmenau University of Technology (TU)

"In the 'PRIMOS' project (Piezoelectric MEMS Resonators for integrated RF Reference Oscillator Applications) our Department of Micromechanical Systems worked jointly with IMMS and the TU's RF and Microwave Research Laboratory. MEMS (microelectromechanical systems) unite sensors, actuators and, where necessary, electronic controls in a single component. It was the goal of 'PRIMOS' to develop silicon-based MEMS resonators for the frequency range above 200 MHz. It is the intention that they should in future replace quartz resonators such as those which create time signals in computers. Quartz resonators cannot be manufactured in combination with microprocessors but require subsequent integration. MEMS as clock generators can be manufactured in silicon together with the integrated circuits. They are, in addition, smaller, robuster and cheaper. The MEMS resonators which are so far commercially available are capacitively excited and are not suitable to high frequencies. Because those developed in the 'PRIMOS' project have piezo-electric coupling, they open up the possibilities of much higher frequency ranges.

For the MEMS resonators, it was the task of our department to research and then implement the chip-compatible manufacturing process. We worked very closely with IMMS to optimise the basic structure of the test resonators and the means whereby they suppressed spurious modes. IMMS made a significant contribution to the project on the basis of its expertise in finite element modelling, which for the MEMS elements supported not only static and dynamic simulation but also mode analysis. The Institute incorporated the engineering design directives resulting from our research into its design activities. Using its measurement instruments, it also established the nature of the mechanical motion or the resonators.The staff at IMMS brought to our project not only comprehensive know-how for the various applications but also perfect teamwork to support our joint achievement of the project's extremely ambitious aims. Since August 2012, the 'PRIMOS' outcomes have been serving as the basis for the research endeavour known as 'MUSIK', to the success of which IMMS is further contributing."

Professor Martin Hoffmann, Head of Department, Department of Micromechanical Systems, Ilmenau University of Technology. Photograph: TU Ilmenau.



IMMS

Dr. Jörg Weber, Project Leader and Deputy Head of Life Science Development at Analytik Jena AG. Photograph: Analytik Jena AG.

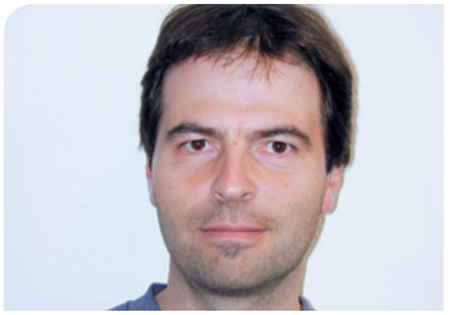
### Dr. Jörg Weber, Analytik Jena AG

"As the spokesperson for the industrial advisory council of 'GreenSense', I am pleased to be able to follow the developments actively. In the project, IMMS is researching and developing a modular technology platform for energy-autonomous smart-sensor networks. These will be able to monitor and control industrial processes better in the future, making them more energy and resource efficient. IMMS performs a great deal of fundamental research in this area and, thus, provides support to small and medium enterprises who cannot afford the effort involved. The work offers great potential for industrial applications, but also for growing markets in life science and medical technology, where we see a rising demand for intelligent microelectronic sensors. We as well as other companies are interested in the outcome of the research project to find new approaches to improve our analysis methods. IMMS is the only research institute for microelectronic applications in Thüringen. As such, the Institute is a valuable support to sensor manufacturers, both in the region and beyond. It has initiated lively exchange of ideas and information with the ten project partners, so that initial thoughts have arisen on many future spin-off projects. The research carried out to date is also already the basis of collaborative projects which are at the planning stage, and to which we are looking forward with enthusiasm. It will be good to keep on with our cooperation. It is a form of cooperation which will continue to underpin the strong position of Thüringen as a technology region."

### Sebastian Bischoff, Bischoff Elektronik GmbH

"At Bischoff Elektronik we have worked jointly with IMMS on the Smart Home Services (SHS) Facility project to develop an energy-efficient hardware and software platform for building automation applications. This embedded system is universally applicable and is suitable both to the control of KNX components and to metering tasks, permitting wireless retrieval of data from wM-Bus, ZigBee or EnOcean devices. IMMS supported us in our development of PCBs and of the system by contributing its comprehensive know-how with respect to the latest microcontrollers, energy efficiency issues and EMC design practice. The Institute also realized the software for the new hardware platform and was responsible for porting the operating system onto it. The expertise in integrated hardware and software development which it brought to bear was vital to the success of the project. The Institute's researchers never lost focus, remained flexible in responding to our desired alterations and were always concerned to achieve smooth cooperation. We shall be delighted if further joint projects are possible in the future and can predict yet more of the successful cooperation."





Daniel Müller, Senior Engineer Baumer Electric AG. Photograph: Baumer Electric AG.

### Daniel Müller, Baumer Electric AG

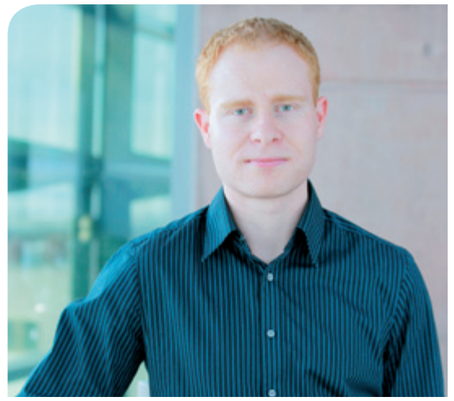
"We had the support of IMMS in the development of one of our new technologies. It involves quick-response sensors that are undisturbed by changes in temperature or by intrusive light and will identify objects in automated handling and assembling equipment. The Institute firstly designed a powerful CMOS Opto ASIC that focuses on integrated tests and fully meets all our specifications for a mixed-signal ASIC. The prototype supplied functioned perfectly. Secondly, and into the bargain, IMMS' work assisted greatly in the backend process. The Institute characterised the chip, developed a mass-production test, assisted us crucially in the selection of an IC package, undertook the management of the assembly, tape and reel and carried out the qualification process for both chip and package. We are deeply impressed with the range of skills and knowledge evidenced by IMMS in helping not only in the entire design process, but also in its application to the mass production stage. The IMMS scientists worked in full and excellent cooperation with us, meeting all deadlines in the schedule, coming fully prepared to our review meetings and maintaining good communication throughout despite the great distance involved. It is our conviction that IMMS will be able to further our business in future, too, applying its knowhow and excellent working practices to later Baumer projects."


Various sensors being tested on Girls' Day at IMMS. Photograph: IMMS.

## IMMS and the encouragement of young academics

It is one of IMMS' highest priorities to bring on the new blood in science. Again in 2012, the research staff at IMMS has been active in pursuit of this goal, inspiring and supporting undergraduate and Master's students in particular. School pupils, too, have been given insight into the work of IMMS by means of events and internships or by having their coursework supervised by IMMS professionals. It is, above all, the students at Ilmenau TU who come to the Institute, but they are joined by students from other universities at home and abroad. All receive a knowledge of methodology soundly based in theory and learn to link this to its practical use. Young engineers from a variety of disciplines – biomedical, electrical or automotive, computer or mechanical engineering, mathematics, mechatronics and physics – are able to work on exciting scientific problems at IMMS, each receiving individual supervision. The Institute also offers training courses and guided tours of the establishment. In all, the year 2012 saw 22 students working at IMMS in the role of intern or student research assistant or in association with the dissertations they were preparing for their BSc, MSc or German "Diplom". The fact that the Institute networks so closely with industry provides the new generation of scientists with the opportunity to work on subjects of practical relevance where the results really matter.

### Benjamin Saft



Benjamin Saft, one of IMMS' researchers. Foto: IMMS.

"Having got to hear of IMMS in one of Professor Sommer's lectures, I did an internship there in 2010, working on industrial electronics and measurement technology. Then I wrote my BSc dissertation at Ilmenau University of Technology in Professor Sommer's department, that of electronic circuits and systems, on computeraided optimisation of an operational amplifier. The subject of my dissertation had arisen in the SyEnA joint project (on synthesis-driven design of analogue circuits), in which IMMS was one of the partners. Afterwards I worked as a student research assistant at the TU and extended my knowledge on the subject. Professor Sommer supervised my dissertation for the MSc, produced at Melexis, which I was successful in defending, and now I have been a researcher at IMMS since May 2012. My work is on the 'GreenSense' project. Pure research in this project is carried out with a view to future application. It therefore provides me with much opportunity for self-development, both professionally and methodologically. I am not limited to applying my knowledge of analogue circuitry and to making a contribution to the design of complex microchips. I have been given the opportunity to study for a PhD on the subject of 'low-power electronics for self-powered smart sensor systems' which will take the issues of the project as its basis. The working environment at IMMS really motivates me to work at my creative optimum. The flexible hours have helped me to make the best use of the times when I can be at my most productive. Researching with an international team is exciting and stimulating, while the discussions with colleagues from such a wide variety of subject areas lead to solutions which are innovative and, at the same time, sound. IMMS, for me, is not only work; I have found real friends among my colleagues and feel that joining the Institute has been more than positive for me, deeply enriching both my private and my professional life."

### Muralikrishna Sathyamurthy

"It has always been my dream to work in scientific research and development projects. It was while exploring the possibilities that I stumbled upon IMMS website and immediately applied for an internship position during September 2009. When I arrived at IMMS, I was greatly motivated by Dr. Eckhard Hennig, who familiarized me with various research activities and student research projects carried out at the Institute. As things there were constantly evolving, I thought I could continuously grow as both professionally and personally at IMMS. And I was defini-

Muralikrishna Sathyamurthy, one of IMMS' researchers. Photograph: IMMS.

tely right. After my internship at IMMS, I carried out further research activities as a Master's thesis student and since February 2011, I have been a scientific research assistant at IMMS in the department of microelectronics, specializing in digital design.

The most rewarding experience from working at IMMS must be the opportunity to work and interact with the talented people here. They are all passionate about and motivated in the work they do. During my stint at IMMS as an intern and Master's thesis student, I thoroughly enjoyed working on research projects in an international and multi-cultural environment. An international student myself, I found that language was no barrier to working at IMMS. Its close association with academic institutions and its strategic partnership with Cadence Academic Network (CAN) helped in enriching my skills in the digital domain through knowledge-sharing sessions and EDA workshops.

IMMS provided a platform (in the form of scientific seminars) where I could present my views and scientific ideas. As a stepping stone, this platform provided me with skills and confidence to present my ideas at international scientific conferences. After my Master's thesis, I was highly encouraged by members of IMMS to present our team's work at SMACD 2012 (the IEEE conference) held in Spain. It was a great experience and this conference certainly proved to be a very good opportunity for me to meet and reciprocate with fellow researchers in my field. My proudest moment in the conference was winning the 'best paper' award for the research activity we had carried out at IMMS during my master's thesis preparation.

When I look back at my career so far, I realize I have grown along with IMMS in a short span of time. IMMS has greatly helped me in fine-tuning my skills and I am very happy to say that 'IMMS is definitely a place for young talented and aspiring scientists.' I feel so proud of being part of and working alongside this dynamic group of talented and inspiring scientists."

## A winning team at SMACD: IMMS and the Ilmenau University of Technology

SMACD stands for the subject of the International Conference on Synthesis, Modeling, Analysis and Simulation Methods and Applications to Circuit Design which was held in Sevilla in 2012 and ran a prestigious competition. First place in that competition went to IMMS scientist Muralikrishna Sathyamurthy, MSc, and Felix Neumann, MSc, of the Ilmenau TU Department of Electronic Circuits and Systems, for their presentation on the subject of UVM-based Verification of Smart-Sensor Systems. Against nine other finalists, the Ilmenau competitors won by presenting the results of the Master of Science dissertations they had written under the tutelage of IMMS. The IMMS "GreenSense" project had acted as trigger for the students to develop their simulation environment for the design of RFID sensor tags. This environment serves not only to optimise individual tags but, into the bar-

Professor Ralf Sommer, Muralikrishna Sathyamurthy and Felix Neumann at the SMACD award ceremony in Sevilla (l to r). Photograph: R. Castro-López.

gain, to optimise the way they interact as to function, timing, power usage and error handling. It enables real application scenarios and constellations of errors to be simulated on a computer. State-of-the-art verification procedures can then also be run so that the simulation will check how correctly the tags will operate in use. Messrs. Sathyamurthy and Neumann also presented a method by which functions of the RFID sensor tags might be evaluated and power usage by the in-chip routines optimised at an early stage.

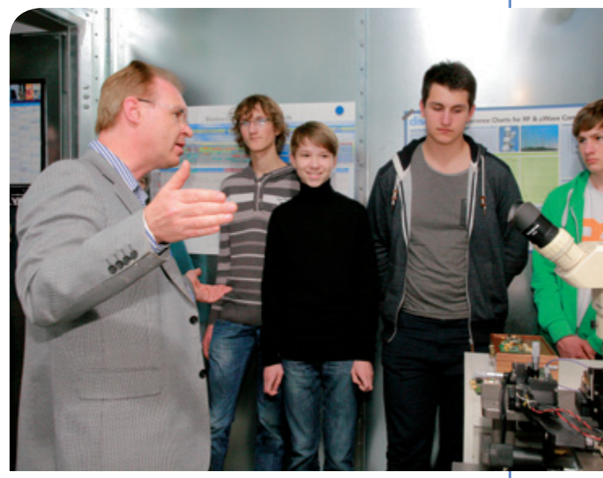

Professor Burkhard Utecht (l.), Director of Thüringen's Universities of Co-operative Education, and Hans-Joachim Kelm signing the agreement. Photograph: IMMS.

## Increased Involvement with the Berufsakadamie in Eisenach

In the 2012–13 winter semester, IMMS and Thüringen's Universities of Co-operative Education, among them the Berufsakademie in Eisenach, signed a contract of cooperation so that teachers from IMMS might contribute to the high academic level offered there. Research and development themes from IMMS are now being included in the lectures at Eisenach on matters of automation and micro-controller programming. For example, the teaching includes demonstration of design methods for automation equipment using scenarios and model-based design, which number among IMMS' research fields. To assist in classification of signals, examples of use are adduced from the research on smart sensors. This kind of stimulation of interest in current developments is important to the professionalisation of the training offered by the Berufsakademie. As BSc and MSc dissertations are supervised by IMMS staff (in 2012 there were four students for the BSc supported in this way), the benefit of absolutely up-to-date research also accrues to the small and medium-sized enterprises which have set the tasks.

## Winners and other pupils from Erfurt and Lörrach at IMMS on the "Jugend forscht" scheme

At the beginning of November, 2012 a visit was paid to IMMS by pupils from Erfurt's Albert Schweitzer Gymnasium and Lörrach's Phaenovum pupil research centre. The former works closely together with IMMS on internships. The eventful day began with a lecture by Professor Ralf Sommer, who then took the pupils on a guided tour through the laboratories and the rest of the Institute. This was followed by a presentation of their research given by the Year Eleven pupils. Animated discussion both among the students and with the IMMS staff ensued. For a particular highlight, which was the presentation by Christian Dreier and Fabian Bronner, the press was also present. This presentation had been crowned in September by the Chancellor's Prize for the most original work in the "Jugend forscht" scheme. The title was "Musik in Super-Stereo – Rêverie de l'acoustique". With their innovative technology, the two pupils produced a realistic spatial listening experience surpassing the sound achieved in any conventional stereo equipment. Their technique was to direct some of the microphones in a recording of a concert not directly onto the musicians but onto the ceiling and sidewalls. Both students have been at the Ilmenau University of Technology since October 2012, Christian Dreier studying Electrical Engineering and Fabian Bronner Computer Engineering. In their studies they are receiving some supervision from, among others, Professor Ralf Sommer, who was the initiator of the academic exchange offered to the young researchers originally.



Professor Ralf Sommer with pupils from Erfurt and Lörrach. Photograph: IMMS.

## Lecture to Ilmenau's Children's University (Kinderuni)

We can hear the different sounds of musical instruments and of voices but we can't see them. Or can we? In the lecture entitled "Sounds and Vibrations – seeing and altering music and voices", sounds and voices were seen and were, indeed, changed. Professor Sommer, who is Head of Science at IMMS, and Doctor Eckhard Hennig, Scientific Strategy Manager of the Institute, were assisted by the two national „Jugend forscht" winners of 2012, Christian Dreier and Fabian Bronner, in unravelling the puzzle of how to-

Tests on Girls' Day: shake detectors. Photograph: IMMS.

Professor Ralf Sommer at Ilmenau's Kinderuni. Photograph: IMMS.

nes and noises can be made visible. In two events, to loud acclaim, they gave a practical demonstration. More than 1300 pupils in all, aged between eight and twelve years, saw and heard their demonstration of the way that sounds and, above all, voices can be completely changed. As the lecture was such a success it is to be repeated on 25th May 2013 during the local "Long Night of Engineering", die Lange Nacht der Technik Ilmenau.

## IMMS contributions to pupil events

Three female scientists from IMMS accompanied the voyage of discovery in which Year Five schoolgirls from two of Ilmenau's selective secondary schools participated on **"Girls' Day"**, 26th April 2012. By playing instruments and by experimenting, the pupils were able to experience the types of vibration there are, finding out how to make them visible, how they are used and how they can do harm. The visitors were also given an insight into how researchers' work influences everyday life. The fact that the event was a sell-out and the feedback from the visitors more than positive has inspired IMMS to provide yet more of the same thing in the coming year.

Ilmenau celebrated an **All Generations Week** and IMMS provided guided tours in that context, the specific event being part of the "Wirtschaftswandertag für Gymnasien", held on 11th October 2012, the purpose of which is to give schools experience of science and industry. This scheme is organised by the German Confederation of SMEs. Numerous Year Elevens and Twelves took this opportunity of testing intelligent sensor systems, being guided through mechatronics and measurement labs by research staff and being given much food for thought. As further schools support, IMMS is providing **mentors** for three Year Eleven pupils from the special mathematical and science classes in the Albert Schweizer Gymnasium of Erfurt who have to do a course work known as their Seminarfacharbeit and have taken radio wave propagation in the 630m frequency band as their subject.


Dr. Christoph Schäffel, Head of Mechatronics, taking pupils from the two Ilmenau selective secondary schools round the IMMS mechatronics laboratory. Photograph: IMMS.



# New projects in 2012, networking and life at the Institute

## New projects in 2012

"EFSUES" kick-off at Erfurt-Weimar Airport with the IMMS sensor node. The Institute has created an energy-optimised transmitter which will be used in future at the airport and is based on the node. Photograph: MDR THÜRINGEN JOURNAL.

### "EFSUES" – safe, efficient airports

February saw the start of IMMS' collaboration with SMI GmbH and Erfurt-Weimar Airport on research and development which will make the airports of the future more efficient. As this demands innovative procedures of wireless location determination, new techniques are being investigated, developed and tested in the "EFSUES" project. "EFSUES" aims to detect the presence and position of aircraft, vehicles and people with such certainty that take-off and landing can continue safely whatever the weather or visibility conditions. It will be possible with the aid of the system to employ special vehicles safely and efficiently, to minimise waiting time for aircraft and to improve traffic safety on the airport apron. IMMS' skills in and knowledge of wireless sensor networks are being drawn on for the low-energy transmitters which will serve the object-location system.

### "GreenSense"

A new research project named "GreenSense" started in June at IMMS. It is funded by the Thüringen Minstry of Economy, Employment and Technology (TMWAT) and the European Social Fund (ESF) under grant no. 2011 FGR 0121 and is supported by an industrial advisory council drawn from local and regional enterprises. Its aim is to research and develop a modular technology platform for energy-autonomous smart-sensor networks. The sensor networks are intended for use in a wide range of future scenarios, particularly in the monitoring and control of industrial production, transport and operational processes, so that those processes become more energy-efficient and less resource-intensive. The researchers are developing hardware solutions for equipment that senses multiple parameters with embedded electronic signal processing, all at low cost and a high level of energy efficiency. Where access is difficult and the cost of the application must be kept to a minimum, energy harvesting solutions have already been designed for operating energy-autonomous wireless sensors.

Dr. Jörg Weber of Analytik Jena AG,(back row, 4th from r.), advisory council representative, with other members and with Dr Eckhard Hennig (back row, 2nd from l.), project coordinator, and the directors of IMMS, Professor Ralf Sommer, (l.) and Hans Joachim Kelm (r.) at the "GreenSense" kick-off meeting. Photograph: IMMS.

"sMobiliTy" project start; at the IMMS premises in Erfurt, partners and friends of the project, representatives from press, politics and ministries were all able to test electric vehicles and view exhibits from feasibility studies, among them the sensor system being developed by IMMS for the "tactile" road. Photograph: IMMS.

### "sMobiliTy"– Electric mobility to become a reality

"sMobiliTy", a project started in October at IMMS and funded by the BMWi (the German Federal Ministry of Economics and Technology), aims to advance electromobility by having the hitherto separate technical systems of vehicles, the road infrastructure, and the electrical grid communicate with each other. Electric vehicles (EVs) have a shorter range and and a longer recharging time than conventional cars, which means that information on traffic jams, electricity prices, range and charger locations is of great importance to the driver. The project partners, who are 10 in number, enterprises and research establishments in Thüringen are developing two demonstrators. A new IT system platform will facilitate navigation through the city of Erfurt, optimising the range and the journey time by registering current local traffic data. Load-related electric fuel price tariffs will ensure that EVs are recharged at the particular times when much renewable energy is being fed into the grid. IMMS is doing the R&D on a new type of sensor system to register data such as the number, class and speed of vehicles on a "tactile" road. In addition, the Institute will enable the secure transmission of these data to the central traffic monitoring and management system and develop a wireless environmental monitoring system.

### New design methodology for MEMS

A completely new universal type of design methodology for MEMS (microelectromechanical systems) is at present being created. It closes the gap between manufacture of the systems and their integration into products. On it, a DFG (German Research Foundation) group is working together with a powerful national consortium of representatives from research settings, universities and the semiconductor industry. The methodology is likely to reduce design time by 30% and raise the marketability of MEMS by 50%. The plan is to use the same design methodology as is used today for the integrated circuits in such equipment as smart phones and tablet PCs, which are designed systematically top-down on the basis of models, using ever smaller building blocks. Similar, thorough-going and unified system design is to be made feasible for mechanical sensor-and-electronics systems. The tool gap, or discrepancy, between MEMS design and ASIC design is to be eliminated. Development time is to be shortened because redesigns are needed less often. As a result, MEMS components will get onto the market faster.

### "MUSIK"

There is a German Research Foundation (DFG) working party on "MUSIK", which stands in German for "multiphysical synthesis and integration of complex high-frequency circuits". The close cooperation, started in August 2012, is between IMMS and Ilmenau TU RF and Microwave Research Laboratory, the Ilmenau Institute for Micro and Nanotechnology, the Ilmenau ZMN, Centre for Micro- and Nanotechnology, and the Ilmenau Department of Electronic Engineering, together with the School of Technical Electronics at the University of Erlangen-Nürnberg. The various researchers will cooperate on the transfer of the amplifying, controlling, oscillating and switching properties of MEMS to achieve multiphysical synthesis and integration of complex radio frequency (RF) circuits The industrial relevance of the research is evidenced in the fact that the partners lined up to be associated with transfer projects are Cadence, Coventor and X-Fab AG Erfurt.

### "MEMS2015"

A high-powered national consortium has come together in the industrial research project funded by BMBF which has the name "MEMS2015" and started in September 2012. The intention is to make innovation in equipment and plant manufacture possible by means of new methods of designing MEMS for modern, high-performance sensor and actuator systems. Participants are Bosch, X-FAB, Cadence, TETRA, Carl Zeiss and Coventor, who are semiconductor manufacturers, EDA suppliers and EDA users on the one hand, and, on the other, our Institute, the University of Bremen and the München University of Technology.



IMMS

The intention is to produce not only processes and process data for IMMS, but rather to meet the challenges in combining the design procedures for MEMS into a start-to-finish design system for sensor and actuator systems, and the challenges in modelling MEMS for the development of the end product. Gaps will be closed between semiconductor and sensor manufacture and the end use, gaps which have so far stood in the way of wide use of MEMS in fields relevant to professional and safety applications. The new methodology will be validated in the field.

### Coventor workshop

To kick off the "MUSIK" and "MEMS2015" projects, IMMS sent out invitations in October to its research partners, offering a two-day workshop in which Aurelie Cruau, Coventor trainer, presented a variety of software packages and demonstrated methods of modelling of MEMS multiphysically. On the one hand, the software uses the finite elements methods and simulates the technological processes of microsystems; on the other, it combines into larger networks a concentration of basic elements which have been modelled and parametrised. This bridges the gap between field simulation which is computation intensive and the simple rules of thumb found in books which are not wholly accurate. In the presentation, the emphasis was on tools which make rapid design of inertial sensors (for instance) possible using the accompanying library elements. The tools also offer the means of designing the sensors which consist in MEMS and ICs because they have interfaces with such electronic design tools as Cadence. Animated discussion was stimulated by the mixture of presentations and practical experimentation. The scientists addressed many issues that they meet in their projects while trying to eliminate the "tool gap", or discrepancies in designability that exist between the design systems for MEMS and ASICs. The projects all aim at achieving a "Lego brick" solution so that heterogeneous systems are designed in harmony as a seamless hierarchy independent of the type of technology, with the end result that fabless design is also a possibility for MEMS. Development partners such as IMMS will then be able to make these technologies capable of use by SMEs, small and medium-sized enterprises.

### "3DNeuroN" – Bio-Mimicking the brain

Since October 2012, IMMS has been working closely with the Institute of Biomedical Engineering and Informatics and the Centre for Micro- and Nanotechnologies at the Ilmenau University of Technology and the University of Tampere, Finland, on a new 3-dimensional low-power, low-noise sensor/actor electrode array for the measurement and stimulation of neuron activity. A 3D array containing 800 or even 1000 electrodes will stimulate neurons according to an unrestricted programme and will record the resulting reactions and behaviour in three dimensions. The research project is set to last 30 months. Its name is "3D neuronal network dynamics" and the goal is to give optimal support to the healing process of nerve tissue which has been damaged by illness or injury.

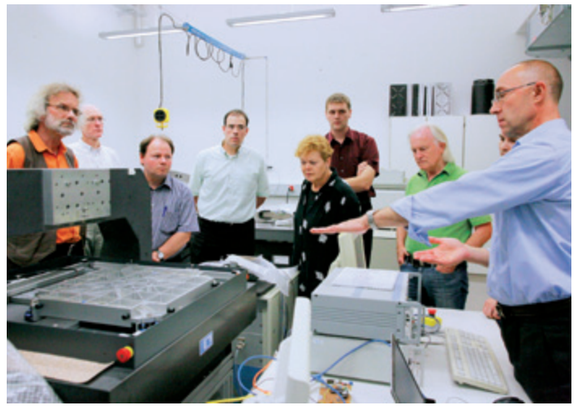
Coventor workshop at IMMS. Photograph: IMMS.

3DNeuroN

### Innovative system for in-ear monitoring

IMMS will develop a new system of natural audio reproduction with in-ear monitoring in conjunction with the iRock network. Because natural sound depends on the position of the artist on the stage, the new system will achieve the necessary adaptation. The new development is intended to appeal to as many musicians as possible, and so, firstly, the system can be adapted to the artist's subjective auditive perception by individual settings. Secondly, the cost of the system should kept down. IMMS is working on a system using wireless sensors in various on-stage positions to localise the musicians. It is a system with the benefit of rapid stage set-up and short measuring times. Wireless sensor networks have long been a research focus at IMMS. Transfer of knowledge obtained into various applications has already taken place. To meet the demands of in-ear monitoring for the musicians themselves, the Institute intends to develop a belt pack as transmitter and receiver.

Embedded Linux workshop organised with OSADL at IMMS. Photograph: IMMS.



Dr. Christoph Schäffel (r.), Head of Mechatronics at IMMS explained a variety of precision drive systems to representatives of the regional German Quality Association (DGQ) in the Institute's laboratories Photograph: IMMS.

## Networking

### AMA: Postgraduate seminar

February 2012 saw IMMS holding a seminar entitled "Embedded Systems en Route to the Smart Sensor". The scientific organiser was Professor Hannes Töpfer. The postgraduate seminar has been an annual event for several years offered by the German Sensor Science Association (AMA). The fundamentals of creation, commissioning and programming of embedded systems were presented, as were open-source approaches and how these systems could be programmed and tested using existing PC infrastructures. An explanation was given of their use in realistic scenarios, and of the inclusion in sensor networks by means of conventional LANs and buses. Various examples of practice were given. The knowledge of those present was brought up to date and they were greatly stimulated. They evaluated the event as outstanding.

### OSADL: Workshop on Embedded Linux at IMMS

In conjunction with the Open Source Automation Development Lab (OSADL), IMMS organised one of the workshops in the Embedded Linux series. The subject was "Opportunities, Practical Approaches and Legal Aspects of Open Source", and the dates were 24 and 25 April, 2012. This was a successful continuation of the series; the participants represented various countries. The matters in the title were addressed by professionals in their fields. In a practical session, the audience was given insight into the programming of Embedded Linux with real-time capability on an embedded system. From this, the participants went on to create for themselves initial real-time applications for an industrial-standard embedded system. The practical examples and exercises, in particular, but also the lectures, were highly acclaimed by the participants. The next such workshop will be held in June, 2013.

### DGQ: Regional Quality Management Meeting at IMMS

Together, in July 2012, IMMS and TETRA (a local company) demonstrated at one of the regional meetings of the DGQ (German Quality Association) the great potential of sensor science for the quality management of high-tech SMEs. IMMS presented a specific optical quality assurance process for membrane-based MEMS (microelectromechanical systems), which reduces the reject rate for full MEMS or their components to a minimum. MEMS are structures that rarely exceed a few micrometres in size and are composed of sensors and the control electronics for acquisition of (for instance) temperature, pressure or acceleration data, all on a single chip. They are too sensitive for mechanical contact. The process which IMMS has helped to develop tests the tiny structures indirectly, by vibrometric analysis of the eigenfrequencies and the determination of the geometric and material parameters of relevance to manufacture. After the demonstration, the representatives from DGQ were given guided tours of the IMMS laboratories and the TETRA premises, discussing as they went the optimum quality management system of the future for the overlap area between research and industry.



### Silicon Saxony: Cyber-Physical Systems Working Party, led by IMMS

Silicon Saxony e.V., a network for the semiconductor, electronics and micro-systems industry, has founded a new working party on CPS, cyber-physical systems. With Uwe Gäbler of Infineon Technologies, Dresden, and Dr Wolfgang Sinn, Strategic Marketing Manager at IMMS at the head, a centre of excellence is being set up for this new technology, where in future those involved in the relevant research and science will come together on a regular basis. The Centre will be a determining factor in the market. Cyber-physical systems constitute one of the early steps on the route to the Internet of Things and Services, the name given to the future means of linking real world services to the Internet. The effect will be that everything communicates with everything else. It is possible that, in close cooperation with German Mittelstand companies, the foundation for "Industry 4.0" may be laid, so that central Germany becomes the hub and control centre for CPS. Cooperating members are TU Dresden, Infineon Technologies Dresden, T-Systems, IMMS, ZMDI, Fraunhofer IPMS und IVI.

## Life at the Institute

When the annual **Companies' Run for Thüringen** (Thüringer Unternehmenslauf) was held in the old city centre of Erfurt on 6th June 2012, IMMS staff took part for the third time. In the men's race, the IMMS runners achieved 167th place out of 254 finishing teams, so that in spite of heavy competition, they successfully defended their previous year's achievement among the midfield. All the Institute's runners improved on their previous best, not only in performance but also in enjoyment. The ladies' turn came in the **Rodel Cup**, which is a luge race organised (in 2012 for the fourth time) by the BVMW, the German Association for Small and Medium-Sized Businesses. Ute Oberhoffner and Jan Behrendt, who are patrons of luge and olympic gold medalists in the sport, provided instruction. Bianca Leistritz of IMMS won the Rodel Cup in 6.814 seconds. Third came Silvia Krug in 6.860 seconds.

The Advent period saw the Institute inviting the staff's children to join their parents on a **Christmas Crafts day**. The young artists, aged between three and eleven, made decorations for the Christmas tree in the IMMS foyer. The drawings and paintings were of such high quality that the Institute had them sent as season's greetings to customers and research partners.

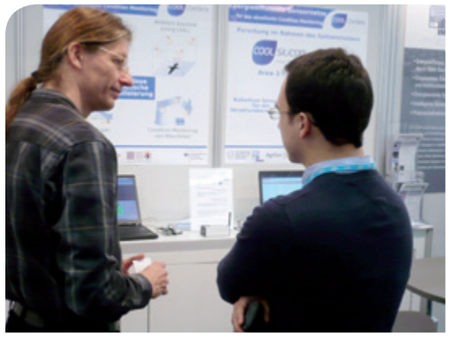


Christmas crafts. Photograph: IMMS.

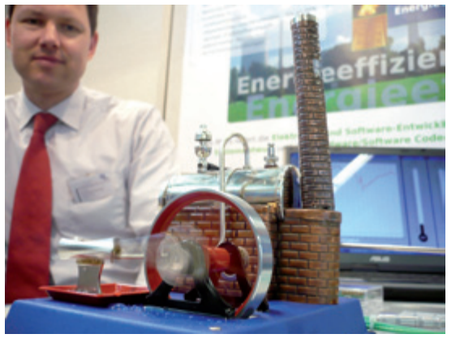
Top left:
The IMMS team at the Companies' Run in Erfurt. Photograph: F. Nowak.

Below left:
Bianca Leistritz and Silvia Krug, Rodel Cup winners. Photograph: IMMS.

# Trade fairs, conferences, workshops



At Embedded World 2012, IMMS exhibited its combinations of energy-efficient hardware with open-source software. Photograph: IMMS.



Among other IMMS exhibits at Sensor+Test 2012 was a high-temperature sensor system for greater energy efficiency in gas-fired power stations and combustion engines (cf. p. 30ff). Photograph: IMMS.

## Trade fairs

**embedded World 2012**
Major embedded event for the whole value chain of embedded system technology, Nürnberg, 28/02/2012 – 01/03/2012

**Sensor + Test 2012**
Trade fair "from sensors to evaluation": system expertise for measuring, testing, and monitoring tasks in all industries, Nürnberg, 22/05/2012 – 24/05/2012

## Conferences and workshops with presentations and contributions by IMMS

**embedded world conference 2012**
Nürnberg, 28/02/2012 – 01/03/2012

**MBMV 2012**
15th Workshop (in German) on methods and descriptive languages for modelling and verifying circuits and systems, Kaiserslautern, 05/03/2012 – 07/03/2012

**GeMIC 2012**
7th German Microwave Conference, Ilmenau, 12/03/2012 – 14/03/2012

**Materials Day, Thüringen 2012**
Weimar, 14/03/2012

**9th IEEE SSD 2012**
International Multi-Conference on Systems, Signals and Devices, Chemnitz, 20/03/2012 – 23/03/2012

**Workshop "Cyber Physical Systems"**
provided by Applications Section, Silicon Saxony registered association, Dresden, 29/03/2012 – 30/03/2012

**ICMCTF 2012**
International Conference on Metallurgical Coating and Thin Films, San Diego, USA, 23/04/2012 – 27/04/2012

**DASS 2012**
Workshop on circuit and system design, Dresden, 03/05/2012 – 04/05/2012

**EDA Workshop 2012**
Design Technology Conference, Hannover, 08/05/2012 – 09/05/2012

**CDNLive! EMEA 2012**
Cadence User Conference, München, 14/05/2012 – 16/05/2012

**Actuator 2012**
International Conference on New Actuators, Bremen, 18/06/2012 – 20/06/2012

**12th EUSPEN Int. Conference**
Stockholm, Schweden, 04/06/2012 – 06/06/2012

**erwicon**
Erfurt Economic Congress, Erfurt, 07/06/2012 – 08/06/2012

**elmug4future 2012**
Technology conference, Suhl-Ringberg, 26/06/2012 – 27/06/2012

**7th Silicon Saxony Day**
"Networked into the Future", Dresden, 27/06/2012

**57th IWK Ilmenau**
International Scientific Colloquium (IWK) at Ilmenau University of Technology "Future Energy – Energy for our future", Ilmenau, 04/09/2012 – 05/09/2012

**SMACD 2012**
International Conference on Synthesis, Modeling, Analysis and Simulation Methods and Applications to Circuit Design, Sevilla, Spain, 19/09/2012 – 21/09/2012

**IBA Heiligenstadt 2012**
16th Heiligenstadt Colloquium "Technological Systems for Live Sciences", Heiligenstadt, 24/09/2012 – 26/09/2012

**Leibniz Conference**
14th Leibniz Conference of advanced science "Sensor Systems 2012", Lichtenwalde, 18/10/2012 – 19/10/2012

**ASPE 2012**
27th Annual Meeting of the American Society for Precision Engineering, San Diego, USA, 21/10/2012 – 26/10/2012

**22th IWK Mittweida**
1st Mittweida Workshop "Wireless Sensor-Actuator Networks", Mittweida, 24/10/2012 – 25/10/2012

**6th Conference on Construction and Precision Engineering** Dresden, 08/11/2012

**IEEE ICWITS 2012**
International Conference on Wireless Information Technology and Systems, Honolulu, Hawaii, 11/11/2012 – 16/11/2012

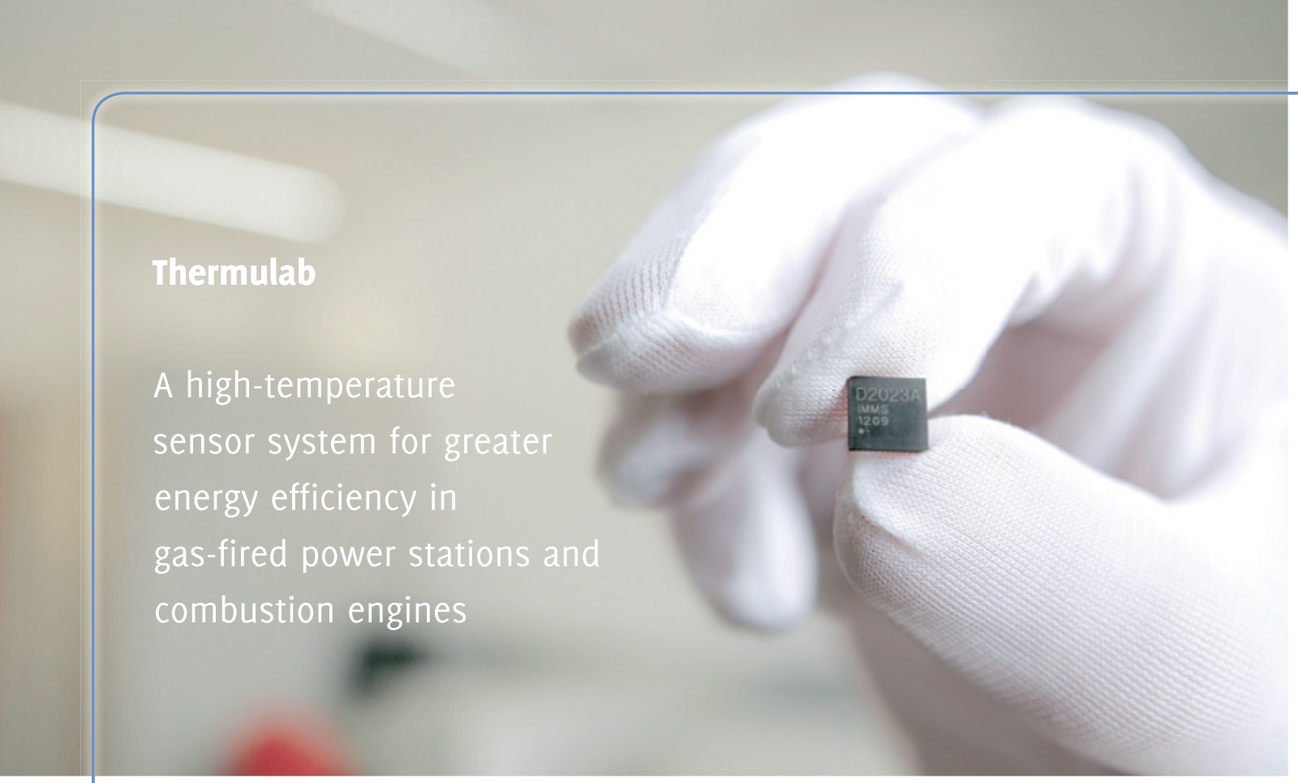
**Workshop "Photonics/Optoelectronics/ Light Applications"**
of the Silicon Saxony registered association (Applications section) and the Cooptics/OptoNet registered association, Jena, 26/11/2012

**6th Dresden RFID Symposium**
of the Silicon Saxony registered association, Dresden, 06/12/2012 – 07/12/2012

**STAFF AT IMMS**

present their work

Photograph:
D. Warnecke,
IMMS.




Microchip with an operating temperature of up to 150°C, developed by IMMS as part of the "Thermulab" project. Photograph: IMMS.

# Thermulab

## A high-temperature sensor system for greater energy efficiency in gas-fired power stations and combustion engines

### Why is it needed?

To achieve high thermodynamic efficiency in gas power stations or combustion engines, the working temperatures are raised almost to the thermal limit of the materials contained in the equipment, reaching up to 1200°C, so that highly accurate measurement of the temperature at various points is required to avoid breaching of that limit. To date, the need has been for sensors with long, extremely well-protected cables leading to the evaluation unit. This unit with its data-processing electronics has had to be kept at a distance which would ensure it never reached a temperature above 100°C.

With their armature, the cables from the sensors were thus extremely heavy and resource-intensive. In the state of the art, it was also customary to use printed circuit cards with several discrete components for the evaluation technology. The aim of the current project has, therefore, been to shrink the data-processing equipment and to integrate it directly into the sensor component, with no cable at all. This necessitates evaluation electronics that work accurately at temperatures up to 150°C. In the context of the Thüringen "Thermulab" research project, IMMS has thus developed an ASIC for a compact intelligent high-temperature sensor system. "Thermulab" stands for the German for thermodynamic multi-sensor technology to monitor high-temperature processes, particularly in exhaust ducts. The ASIC replaces several discrete components with one integrated circuit, offering better performance, greater robustness and more accuvvrate measurement. Networking is simplified by the use of a digital data bus which, also, because there are fewer cables means lighter weight and lower cost. The data from the sensors can be processed on a distributed basis, significantly improving energy efficiency. Sensor merging and data compression achieve much lower data rates, again resulting in lower energy consumption.

### What does the microchip do in particular?

In view of the high number and great complexity of elements composing the integrated microchip, its highly accurate analogue components and its relatively large digital section with microcontroller and memory blocks, plus the operating temperature up to 150°C, IMMS found it necessary to take new design routes and new measurement technology as a means of characterisation. The greatly extended temperature range is at present met by no commercially available circuit solutions. The standard to date has been circuits functioning at up to 125°C. The IMMS microchip, operating at 150°C, will support temperature measurements with a thermocouple to an accuracy tolerance of 1°C in the range from -40°C to 1200°C.

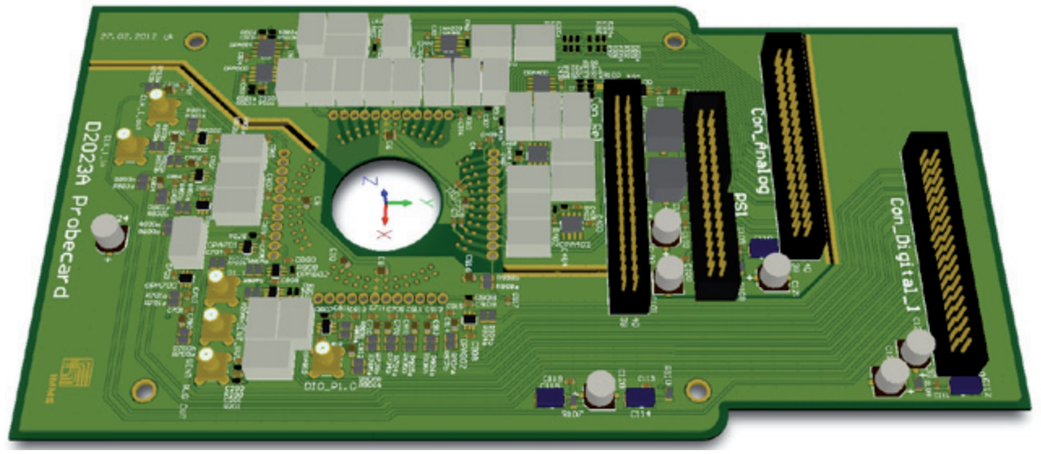



Fig. 1: Layout of the testing card shown as 3D image. Graph: IMMS, Industrial Electronics and Measurement Technology.

There is, however, a disadvantage to thermocouples: the voltage emitted is tiny, around 50µV/K. To calculate a temperature from this voltage, a reference temperature is also necessary. To meet the challenge, IMMS has developed electronics which evaluate very tiny voltage differences, almost without potential, and will exactly determine the temperature at the reference point. The result is an ASIC which amplifies these temperature signals with low noise and then converts them into digital information by means of a suitable ADC. The digital element of the chip analyses the data from the sensor and transmits it in corrected form as a serial data stream. Two PWMs (pulse-width modulated outputs) or one SENT with a driver stage are the means of analysis and streaming. SENT stands for single-edge nibble transmission bus and is an interface used in automotive engineering to transmit data between the sensor and the control device.

### Why did the test setup have to be so complicated?

The complex demands on the microchip – wide temperature range, large digital blocks and highly accurate analogue components – involved great effort for the test setup. It was the most comprehensive and complex setup yet undertaken by the Institute.

IMMS verified and characterised the microchip at the stage when it was on the semiconductor wafer. The testing card necessary uses a "needle spider" to contact the bond islands on the chip and itself contains the test circuit. The research group created the circuit diagram, simulated the circuit, designed the layout and constructed the PCB in four layers. Among the items contained on the PCB are connections to the testing system and 30 relays to put the specified tests into practice (see Fig. 1). Investigation and testing of the finished (testing) card were carried out (see Fig. 2). To enable components to be tested with the same setup after the test had been run on the wafer, the testing card was provided with a slot for the chip socket.

The tests of the microchip were run on the IMMS MTS-1 modular system normally used for semiconductor testing. This test system, developed at the Institute, comprises chassis, controller and tester instruments which fulfil the PXI standard. Seven different PXI testers were necessary for the "Thermulab" testing. PXI stands for PCI eXtensions for Instrumentation. Among the instruments were a high-resolution digital multimeter to measure current and voltage precisely, a digital generator/analyser to produce and measure digital signals, and a digitiser capable of acquiring data from rapid signals. To generate and determine the analogue and digital direct voltages, two PMUs (parametrical measuring units) developed by IMMS specially for the purpose were used. The PXI cards were wired up using custom terminal modules (see Fig. 3) which route the resources of the PXI test instruments to the DUT connections on the testing card (DUT: device under test). The connection of the testing card is to the port module.

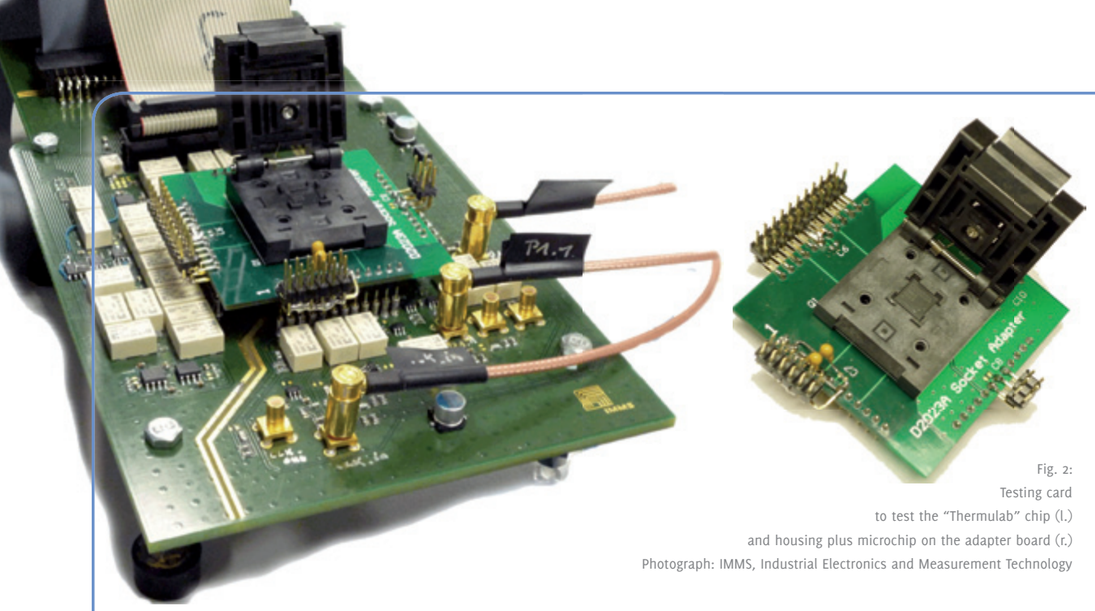



Fig. 2:
Testing card
to test the "Thermulab" chip (l.)
and housing plus microchip on the adapter board (r.)
Photograph: IMMS, Industrial Electronics and Measurement Technology

To achieve extremely accurate testing of all the important parameters within fractions of a second, comprehensive measuring procedures were created for the wafer test using the graphic programming environment LabVIEW®. The vital parameters included the power consumption of the circuit and the currents generated within the chip. Temperatures were measured at both the reference point and the thermocouple. The reference voltage source integrated into the microchip (specially developed for the purpose by IMMS) supplies stable voltage across the temperature range from -40°C to 150°C. There were further tests, those on the automatic error recognition, memory and microcontroller functions.

To characterise the circuit, the Institute examined the ICs extremely thoroughly, calibrating the reference voltage source in the process and making certain settings. As a check, IMMS heated the circuit gently in steps of 10°C from -40°C up to 150°C and measured all the parameters in relation to the reference voltage source at each stage. These results make it possible to calibrate the ICs as early as on the wafer prober.

By way of conclusion, the Institute adapted the necessary application software to prepare it for later use. This involved offset compensation and averaging to increase the accuracy of the IC. The error recognition system internal to the ASIC warns of errors in the application, such as a broken cable or missing sensor.

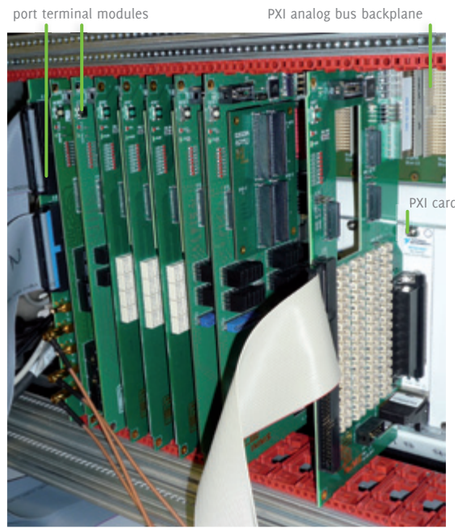


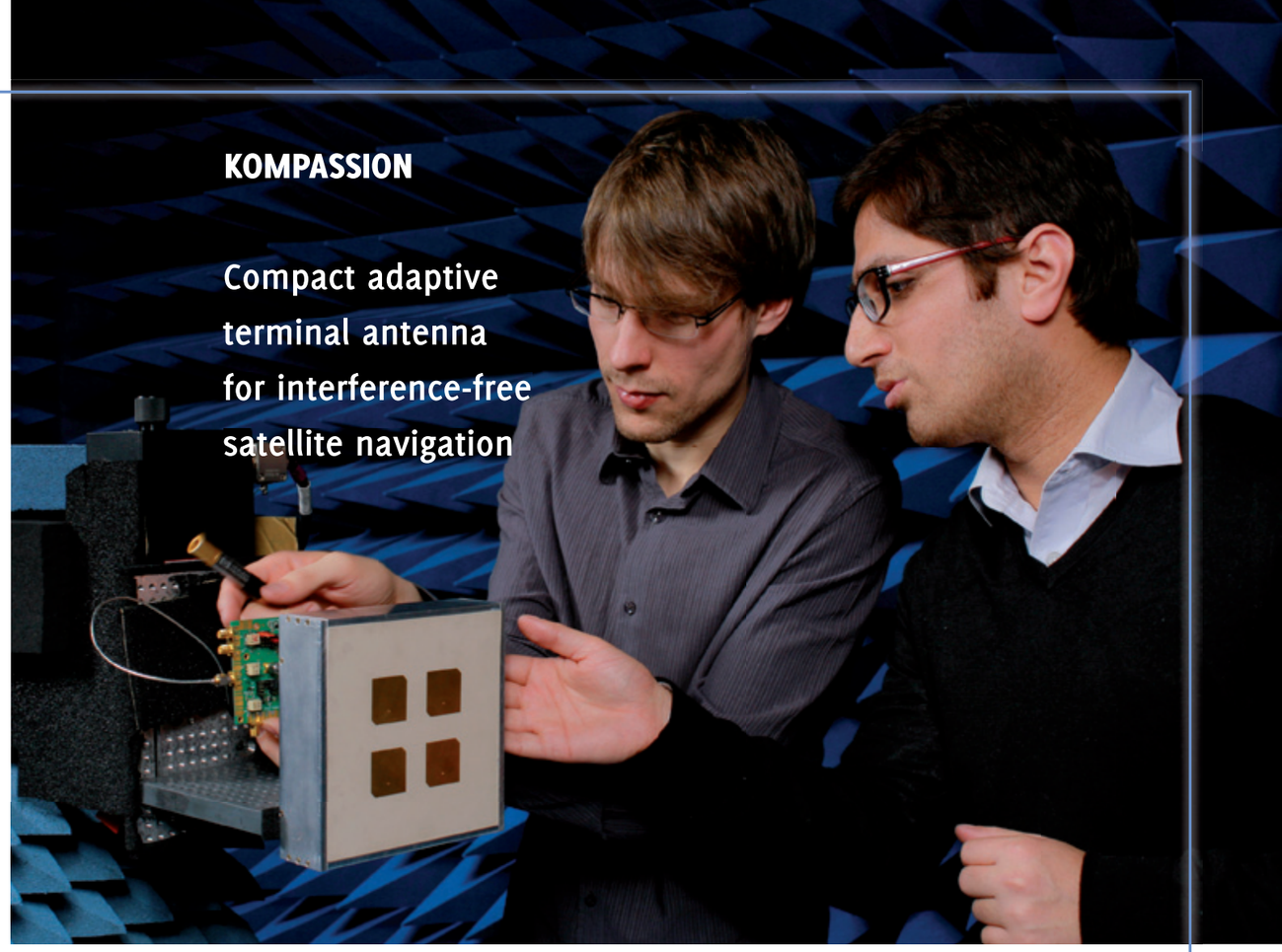

Fig. 3: Test setup showing IMMS MTS-1 and the connecting wires to the testing card. Photograph: IMMS, Industrial Electronics and Measurement Technology.

## What of the future?

It will be possible to achieve further optimisation of the microchip area if a number of test pins are saved and the memory is reduced to half its present size. It may also be possible in future to integrate more external components into the sensor IC. The redesign of the "Thermulab" chip currently taking place is expected to improve even on the accuracy so far achieved.

**Bibliography:**
IMMS published a paper in 2012 on this subject – cf. no. 30 in the publications list, p. 49ff.





# KOMPASSION

## Compact adaptive terminal antenna for interference-free satellite navigation

Project team members from Ilmenau University of Technology RF and Microwave Research Laboratory and from IMMS prepare to take measurements of interference suppression in the University IT Institute's anechoic chamber. Photograph: IMMS.

Unmanned flying vehicles such as quadrocopters are being used ever more. Long-discussed fields of application for this new technology are catastrophe relief services or the autonomous transport of such urgently required goods as donated organs. However, although there has been enormous progress in their development over recent years, these aircraft have not so far been used for safety-critical scenarios. Autonomous movement, it must be remembered, requires absolutely precise navigation.

The challenges, especially those relating to interference mitigation, cannot be met by commercially available satnav receivers, which are subject to errors in or even loss of location signals if the reception conditions are less than ideal. Such conditions arise particularly in urban and built-up areas with many high buildings and other objects which will reflect the signals being emitted by the GPS and Galileo satellites. If large numbers of these reflections overlap at the receiver, processing errors may result. Also, satellite signals are weakly powered and are thus easily jammed by other radio services. Not only deliberate and conscious jamming but also the coexistence of various different communications and navigations systems may affect the reception. There is an example to be seen in the aerospace field. The strong transmissions from classic airport landing support systems interfere with the signals of satellite-based navigation systems. As a consequence, the use of satellite-based navigation for autonomous landing at airports has not so far been possible.

A suitable method of effectively suppressing interference or multipath signals, has proved to be shared use of multiple antennas as group antennas which have customised electronics and algorithms to permit

the adaptive shaping and controlling of the signal beams. Like the human ear, group antennas with signal analysis as a second stage can detect interfering signals together with the direction from which they come and block them out. The distance between the individual antennas will usually be approximately half the wavelength of the signals to be received. A group antenna of this kind is thus naturally much larger than a navigation antenna which consists of a single element. For instance, the edge of a square array with four individual emitters will be about 30 cm long. The size and weight of the receiver have thus often prevented the use of group antennas on mobile platforms.

The "KOMPASSION" project sees IMMS in cooperation with a number of partners developing new designs, technology and algorithms to assist in the manufacture of group antennas distinguished by their compactness. The German Aerospace Centre is in the coordinator role. The other partners are the RF and Microwave Research Laboratory at Ilmenau University of Technology and the Chair of Electrical Engineering and Computer Systems at RWTH Aachen University. To achieve the smaller antennas, the distances between the individual elements have to be reduced. If they are less than half a wavelength apart, the coupling of the individual antennas rises steeply, so that the group antenna loses more and more of its directional sensitivity and thus of its effectiveness. Decoupling and matching networks are being specially developed in the project, together with the appropriate algorithmic signal processing, to compensate for the negative coupling effects. The overall aim of the project is a receiving unit for navigation signals which is only half as big as a conventional group antenna but has the same number of individual elements and which demonstrates the applicability of the processing methods developed.

IMMS is contributing to the project its knowledge and skills on microelectronic integration of analogue and radio frequency circuits. The research is focussed on the development of receiver frontend circuits, which are required so that the weak, radio frequency signals from the satellites can be enhanced for digital processing. The signals have to be amplified and their centre frequency converted. IMMS has to meet the challenge of finding a particularly low-noise implementation of signal processing which is still highly resistant to the interference level and of integrating onto a single shared silicon chip several reception channels which work together coherently. The frontend is thus the link between the group antenna and the digital processing electronics (in which the algorithms for interference suppression are implemented). Currently, there is no commercial solution available which is capable of meeting the requirements for compactness and for adaptation to the system as a whole. It is therefore IMMS' intention to develop in successive stages a frontend chip and the various peripherals ready for a demonstrator.

The circuit diagram of the receiver IC is to be seen in Figure 2. IMMS has elaborated this architecture with the project partners, agreed the conditions and developed the circuit concept on the basis shown. In contrast to commercially available chips, this unit has four decoupled reception paths on a single shared IC. The degree of interference and noise resistance demanded has received particular attention. To ensure coherence among the four paths, all four are driven by a shared frequency synthesizer which is also located on the chip. It will be possible to calibrate the critical components via a digital interface so as to cope with the manufacturing tolerances necessitated by the technology.

IMMS has designed two test chips so far and has subjected them to measurement. Most of the testing was carried out in the Institute itself. The noise measurements on the naked chip were of great interest as far as the continuing progress of the project is concerned. It was possible for us to draw on the long experience of IMMS with characterisation methods for RF circuits and RF technology itself.

Figure 1:
Localisation errors are often caused in conventional satnav receivers by the overlapping of various radio services and by the presence of high buildings reflecting the satellite signals. The problems are solved by adaptive group antennas. These are made more compact in the Kompassion project so that autonomous flying vehicles can be used to assist in safety-critical situations.
Sketch: IMMS

The Ilmenau TU RF and Microwave Research Laboratory has particular skills and equipment for the characterisation of antenna systems shortly before practical application. The receiver system is being tested in the context of the Institute's very close cooperation with the Laboratory, whose head is Professor Matthias Hein. The tests in the anechoic chamber involve real satellite and interference signals and realistic conditions of use. The Laboratory also has state-of-the-art noise measuring equipment that establishes the noise parameters for the whole boards on which the newly developed frontend chips are installed. The investigations carried out so far have confirmed the initial theory. The results have been jointly published with the project partners.[1]

The frontend chip developed by IMMS achieves the high performance required, particularly in respect of noise and interference resistance. Further refinements to the system definition are to be implemented in the frontend by mid-2013 and it will be tested as an element of the demonstrator system. The system will be implemented as a 2 x 2 group antenna, reduced to half the size of conventional types. The project will be concluded with a final test in GATE (the Galileo Test Environment) at Berchtesgaden.

Funding for the project has come from the Space Agency of the German Aerospace Centre, using resources (reference 50 NA 1009) from BMWi, the federal German ministry of economics and technology, as decreed by the federal German parliament.

**Contact:**
Eric Schäfer, M.Sc., eric.schaefer@imms.de

**Bibliography:**

**1** IMMS published several papers in 2012 on this subject – cf. no. 4, 17, 24 and 55 in the publications list, p. 49ff.

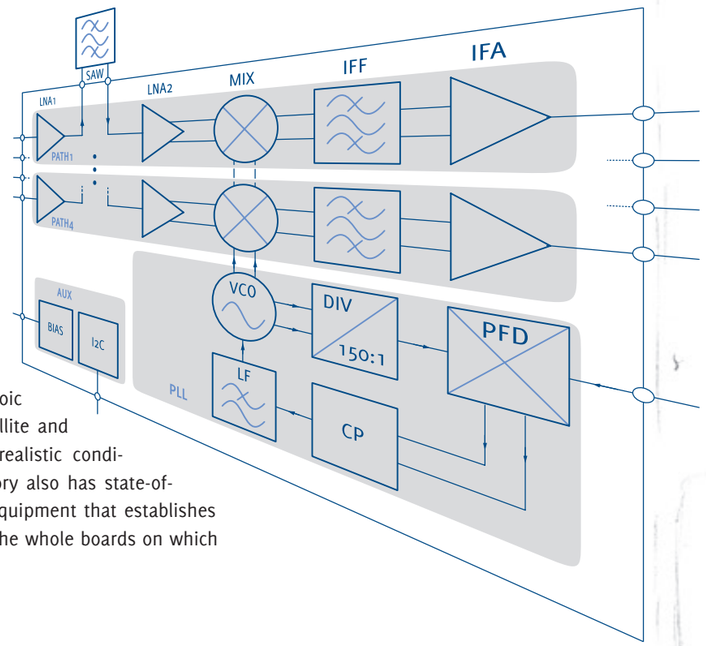



Figure 2: Circuit diagram, receiver IC. Schematic diagram: IMMS.

# TESCA

## Direct mirror drive for Terahertz Scanner

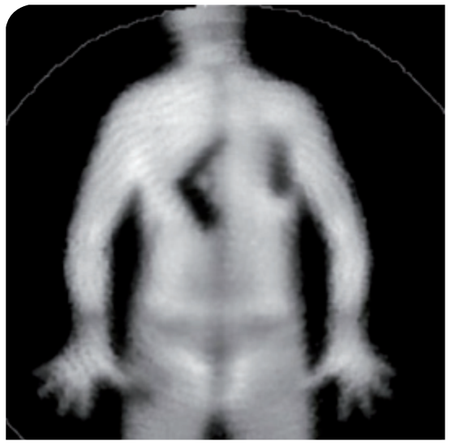
Spl[illegible] Photograph: IMMS.

Installing the scanner mirror into the complete system at IPHT (project partner) in Jena. Photograph: IMMS.

Security checks at airports and major public events involve long queues and much trouble. A “terahertz camera” would enable people to be scanned in future for hidden, possibly dangerous, objects – such as weapons or explosives – effectively scanned as they simply passed by. The acquisition of any object's emissions of intrinsic electromagnetic waves in the THz band carries with it no health risks whatsoever. The technology[1] will render real-time examination from distances of several meters possible.

The idea behind the camera’s technology is the combination of fairly small sensor matrices with a scanning device in the lens, so that the field of view is wide enough. The first generation of such cameras made use of a tilting mirror with a helical scanning track. Movement of this kind avoids frequent acceleration of the scanning mirror with its relatively high inertia. Although the method makes the mirror easy to control, the rotational forces involved mean that the imaging frequency is not high, being limited to 10 Hz. Another problem is that the spiral shape of the scan causes a great deal of data to be produced for the unimportant areas of the image and relatively little for the vital areas.

Figure 1:
Image left: objects tested
(mock pistol, 65g tartaric acid and ceramic knife)
Image right: output from the first generationTHz Scanner
Photographs: IPHT Jena.



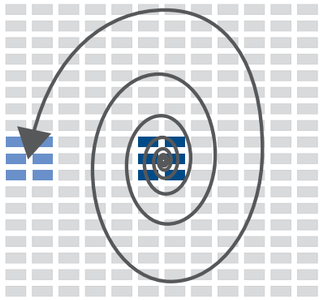


Fig. 2:
Scanning track of the first-generation THz Scanner. Sketch: IMMS.

IMMS' work on the mirror drive has resulted in a crucial component for the next generation of cameras, which permit linear scanning of the field of view and improving the targeting. They also have a significantly higher image frequency, at 25 Hz (figure 3). Improved receiver modules which can be lined up in a single row have been developed by Supracon AG Jena, one of the project partners, and are employed in the new cameras. This means that the demands on the scanner dynamics are considerably different from those in the first generation. A central component of the new THz camera is a mirror lens with a relatively large diameter, about 40 cm. This size is necessitated by the size of the sensor line. The mirror lens in the earlier version was only about 15 cm in diameter. The mirror of the new lens is moved at a uniform speed in order to map the field of view onto a line of receiving sensors. To achieve this, the mirror has to swing through an angle of ±5°. This movement needs to take place as constant at speed as possible and with minimum time spent arrested at the reversal points. Because two images are captured with each full cycle, one on the outward swing and one on the return, for a camera frequency of 25 Hz the scanning frequency necessary for the whole device is 12.5 Hz (figure 4).

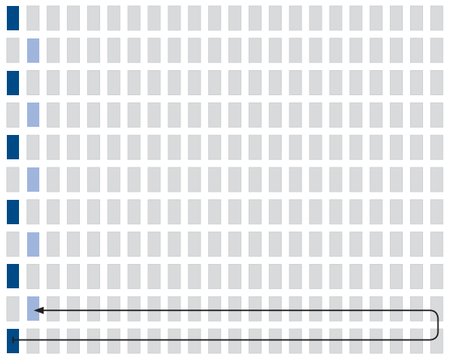


Fig. 3: Linear (therefore targeted) field of view scanning with the second generation THz Scanner. Sketch: IMMS.

The mirror thus imposes a great challenge on the actuators to be used. As it is both large and heavy, and its rotational inertia is considerable. In consequence, very high material rigidity is necessary to avoid deformation from the forces induced. Such a large lens moving at such a high frequency (25 Hz) so accurately has not previously been achieved on any known motion device. It was therefore necessary to devise an innovative, stand-alone solution. IMMS applied its know-how in the field of electro-dynamic direct drives to the problem and developed a new actuator together with the necessary controls. Mechanical movement of a kind which has previously been impossible with geared motors is achievable with electro-dynamic direct drives. The drive system developed by IMMS in the “TESCA” project moves the mirror on a special track (figure 4) at a frequency of 12.5 Hz. The actuator consists of a magnetic circuit with permanent magnets and a moving box coil. The forces and moments necessary were first determined from the mass to be moved and the moments of inertia, then the layout of the magnet actuator was designed. Here, the focus had to be on optimising the energy efficiency of the system so that no additional cooling mechanisms would be necessary in standard use. On the basis of the magnetic and mechanical parameters calculated, a model-based design of the control structure was produced. Then the system behaviour was gradually optimised by means of simulation.

The movement profile required here necessitates the application of considerable energy to achieve acceleration, with consequent heat build-up that could interfere with the system. To help solve this problem, IMMS used permanent magnets for energy storage. They absorb the kinetic energy at the end position of the mirror movement for a very short time and then have it available almost immediately for the accele-

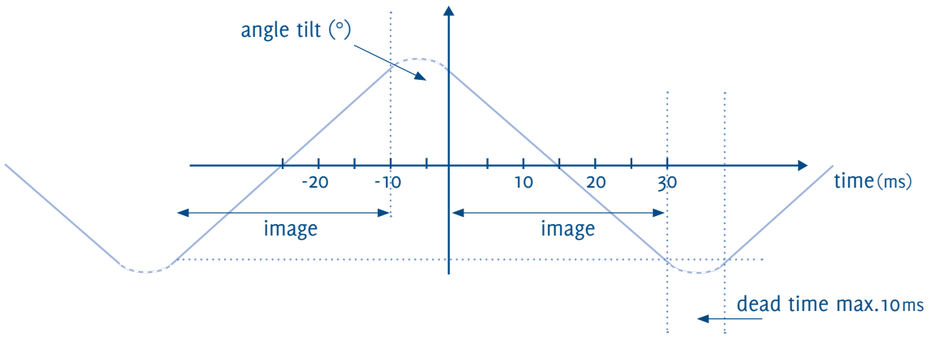



Fig. 4: Tilt cycle of the new mirror drive. Sketch: IMMS.

ration. These magnetic "springs" consist in opposing arrays of permanent magnets exerting repulsive force on each other. There is thus a steep increase in the force exerted at the end positions, while no influence from the magnetic springs is felt over the rest of the swing distance if the movement is at a constant pulsation rate. A number of versions were calculated to achieve optimised movement with the desired accuracy and minimal energy wastage.

To keep to a minimum the mass to be moved, the mirror assembly was designed with a fibre-reinforced support structure. The material employed shows different physical behaviour in different directions. This property is put to strategic use in order to guarantee rigidity of shape in the mirror using as little material as possible. The development, design and construction of the mirror took place in the Institute for composite construction (KVB) at Chemnitz.

The project partners were able to put into operation a prototype of the scanner on a functional model of the THz Camera. Responsibility for the integration of the scanner into the THz Camera lies with Supracon AG Jena.

In the same way as television evolved from the Nipkow disk through the cathode ray tube to the high-resolution flat screen, THz imaging has now also taken its next evolutionary step. This development brings much closer the vision of the sort of security check which would involve no delays, no risk to health, and only an absolute minimum of invasiveness. Moreover, it will be possible to employ the technology of THz imaging in geo-observation supported from the air or from satellites, to facilitate the exploration of natural resources.

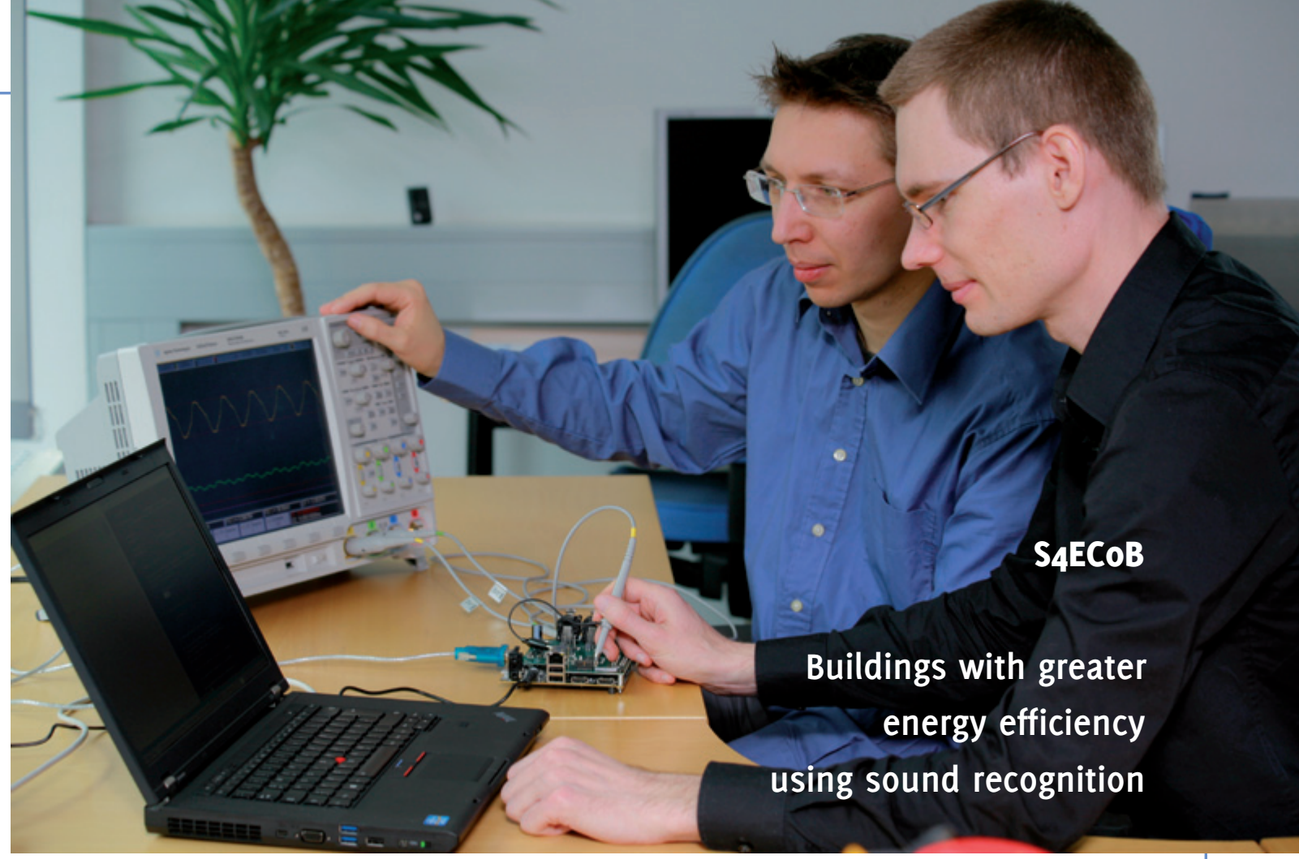
Funding for the project (reference KF2534505AB0) has come from BMWi, the federal German ministry of economics and technology, as decreed by the federal German parliament.

**Contact:**
Dipl.-Ing. Norbert Zeike
norbert.zeike@imms.de

**Bibliography:**

1 E. Heinz, T. May, G. Zieger, D. Born, S. Anders, G. Thorwirth, V. Zakosarenko, M. Schubert, T. Krause, M. Starkloff, A. Krüger, M. Schulz, F. Bauer and H.-G. Meyer, "Passive Submillimeter-wave Stand-off Video Camera for Security Application", Journal of Infrared, Millimeter and terahertz Waves, vol. 31, no. 11, pp. 1355–1369, 2010.





# S4ECoB

## Buildings with greater energy efficiency using sound recognition

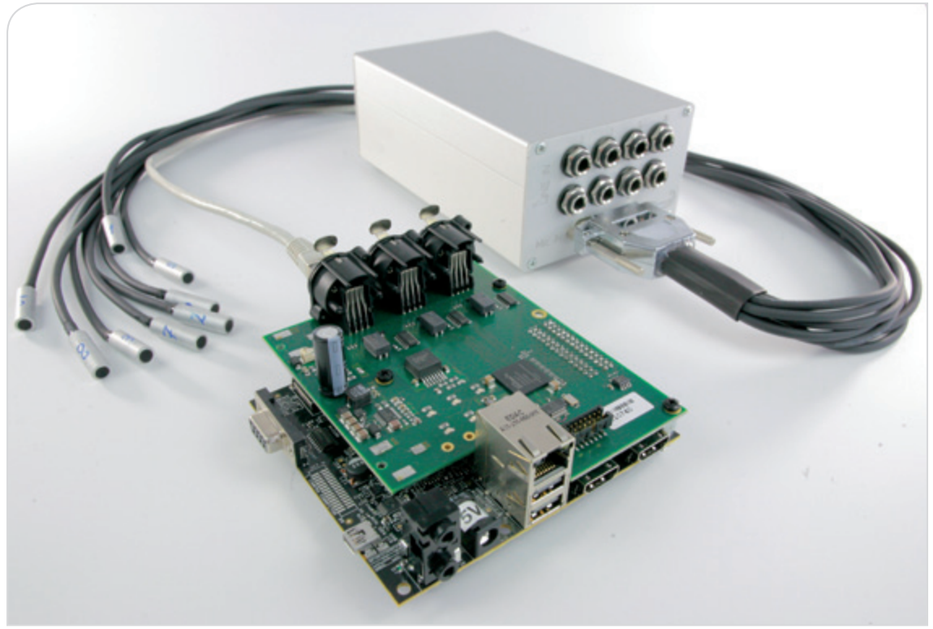
The embedded platform for acoustic signal processing being put into operation. Photograph: IMMS.

Buildings are responsible for a third of the $CO_2$ emissions and 40% of the total energy consumption in the EU. More than 60% of the energy used there goes into HVAC (heating, ventilation, air conditioning) and lighting.[1] As these systems offer the greatest potential for improving the energy balance of buildings, they are the focus of efforts to conserve energy[2] in order to achieve the ambitious "20-20-20" climate goals of the EU member states[3] – improving energy efficiency and reducing greenhouse gas emissions.

This motivation has led to "S4ECoB" – Sounds for Energy Control of Buildings, a 3-year project funded by the EU (ref. FP7-ICT2011-7) in which IMMS and six partners from five EU countries are jointly researching how acoustic data may be used to optimise the energy consumption of systems in major public buildings.

Optimal control of building systems requires knowledge about the number and distribution of people within the building. The performance of HVAC systems depends on the amount of fresh air being fed in, which needs to be increased with rising occupancy levels or, conversely, can be reduced when fewer people are present. The demand for artificial lighting depends on the location of people in the building. Monitoring the occupancy data of individual areas in real-time will thus make optimisation of lighting and air conditioning possible.

Existing building automation systems usually control HVAC and lighting by means of timing schedules, switching between operating points after predefined periods. Sensors are used for monitoring $CO_2$ levels in the air as a means of determining the number of people in individual rooms. For large spaces, however, these are not accurate enough, and they involve disadvantages in their installation, calibration, and maintenance[4]. Using video cameras to determine occupancy is costly in terms of both money and effort. The idea of using sound for monitoring, which is being pursued by the project partners, may well provide a much simpler and cheaper alternative means of monitoring occupancy in real-time and fine-tuning existing building control systems to achieve savings.



The "S4ECoB" system, consisting of a microphone array and an embedded energy-efficient hardware and software platform. The system is capable of determining the number of people in parts of a building based on acoustic data and control building systems accordingly. Photograph: IMMS.

The "S4ECoB" system being developed in the project uses a network of spatially-distributed microphones to pick up sounds in their vicinity. More specifically, eight microphones and their associated electronics for digitising and encoding signals form a microphone array. Up to three of these arrays can be connected to an energy-efficient embedded hardware and software platform, the Audio Processing Unit (APU). The APU will process audio data streams, classify acoustic events, and, from them, estimate the number of people in the rooms being monitored by the arrays. Together, the microphone arrays and the APU constitute a sensor for determining occupancy levels. The data computed by the APU is transferred to a central unit, where it is processed further and building control is adapted to the current situation, thus minimising energy demands.

The system presents numerous challenges. To meet them, IMMS has developed novel solutions within the project, developing the embedded platform that will process the acoustic signals. This involved designing and building adequate hardware and implementing software components. The Institute has also designed and implemented the communications architecture between the components. The innovative architecture and the new methods adopted for the hardware and software implementation have proved to be the key to an embedded signal processing platform with low energy usage that offers not only very high performance but also the advantages of flexibility and low price.

Hardware-wise, the APU is composed of two main components: firstly, an FPGA, a programmable hardware circuit, decodes and preprocesses the audio data streams. Then the processor computes the occupancy level in real-time. IMMS initially investigated the performance of various audio algorithms on a number of embedded systems. Based on this, the OMAP4460 (ARM) processor has been selected (which is, incidentally, also used in smart phones and tablet computers). The FPGA is connected to the processor's external memory interface, enabling data rates of up to 1.6 Gbit/s.

Both the APU and the tasks performed by it are highly complex, requiring an operating system which can be optimised accordingly. IMMS has been extending its know-how in employing and adapting the open-source Linux operating system for years. Linux offers comprehensive hardware support for embedded systems. Extended by RT-Preempt, it gains real-time capabilities, a necessary basis for even more demanding future audio-processing algorithms. It is for this reason that the Institute's researchers have adapted the Linux kernel and developed a driver to communicate data rapidly to the FPGA.

Building upon this, IMMS has developed two additional software components. The first is a program for reading the acoustic data from the microphone array via the FPGA and then processing it using any out of a variety of acoustic algorithms, provided in a modular fashion and selectable at runtime using plug-ins. The second component is responsible for the communication between the APU and the central server, which utilises a TCP/IP network infrastructure. The data transferred are secured by either being encoded using a Transport Layer Security (TLS) protocol or being transferred over a Virtual Private Network (VPN).

A program named "APU Gateway" represents the counterpart on the central server and has also been developed at IMMS. On the one hand, it manages the individual APUs connected to the server by dynamically establishing and terminating connections and monitoring their status. On the other hand, it receives the data sent by the APUs and makes them available to other components on the server. It is crucial to the proper functioning of the acoustic algorithms that the internal clocks of all the APUs on the same network and of the central server itself remain synchronised as closely as possible with each other. To ensure this, the IEEE 1588-2008 Precision Time Protocol is employed, which will keep the time deviation among components below 300µs. This has been confirmed in a number of tests.

In partnership, the project's first hardware prototypes have been manufactured and put into initial operation. A first network has already been set up for testing purposes, the newly-designed components verified and the system's functionality proven. The system is to be installed at three demonstrator sites in April 2013. These are Milano Linate Airport and the two shopping malls "Principe Pio" in Madrid and "Maremagnum" in Barcelona. The project is due to end in September 2014: from October 2013 onwards, it is intended to optimise existing building control systems in selected areas of the sites using the newly-developed system. Throughout that period, energy consumption will be monitored continuously in order to determine actual savings and prove the overall functioning of the system. At a later stage, it will be possible to build a cost-optimised sensor on the basis of the project results and start mass production, allowing for acoustic monitoring to be installed in arbitrary public buildings and thus a genuine contribution to the achievement of the climate goals to be made. A further development might even be to extend the sensor by security features, such as the detection of glass breakage.

**Contact:**
Dipl.-Ing. Sebastian Uziel
sebastian.uziel@imms.de

**Bibliography:**

**1** Bertoldi, P. and Atanasiu, B. Electricity Consumption and Efficiency Trends in the Enlarged European Union, European Commission, Institute for Environment and Sustainability, 2007.

**2** Directive 2010/31/EU of the European Parliament and of the Council of 19 may 2010 on the Energy Performance of Buildings (recast), 2010.

**3** Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the committee of the regions – 20 20 by 2020, Europe's climate change opportunity, Brussels, Jan 23, 2008.

**4** L. Damiano, Issues Concerning the Difficulties in Applying DCV with CO2 Sensors, October 14, 2003.

# SHS-Facility

## An intelligent system for building automation

SHS system node. Photograph: R. Peukert, IMMS.

Housing has been changing radically over a period of years. Empty buildings due to demographic change, a new legal framework and also the availability of new technology have forced landlords and real estate administrators into a rethink. The challenge now for the housing industry, with its typical investment period of many decades, is to achieve the sort of flat or apartment that can be individually tuned, is suitable to every age and stage of life, saves on energy and is online to connect its tenants to the world. The inhibiting factor for innovation is that any investment will benefit the tenant more than the investor. The effect of this is that innovatory concepts have first to meet the challenges not only of refinancing and sustainability over a long future but also of openness to future changes in technology and use.[1]

IMMS is contributing to the Smart Home Services (SHS) network, which is at work on the various problems. The network is made up of the Verband der Thüringer Wohnungswirtschaft (a regional housing sector association) and a number of companies and research establishments. The joint project receives financial support from the Thüringer Aufbaubank (Thüringen Development Bank) under reference FKZ 2010 FE 9073 and the overall name of "SHS-Facility". Its stated aims are the development of a smart home system and services based on it, to benefit both the tenants and the operators of the property.

There is certainly a need: none of the currently available home automation solutions for locks, fire and smoke detection or for technical monitoring is fully satisfactory. All vary from manufacturer to manufacturer, operate as standalone systems and, frequently, cost so much that they are unaffordable. With the SHS project, the intention is to achieve an alternative, appropriate system

- that is a total system for application in housing management, both the home services and the facility services, so that synergy effects become a possibility,
- that reduces the investment costs by employing open, future-compliant architecture with a shared standard communication infrastructure,
- that provides networked analysis of the information generated, together with data security and privacy demanded by the law and desired by users.

## A central component of Smart Home Services

IMMS has contributed significantly to the Smart Home Services solution by creating a shared communications infrastructure to be used by all the sensors, actuators and processing units involved. There is to be a single pivot enabling integration and coordination of the various subsystems: the SHS system node, a compact, low-priced, energy-efficient mini computer that will acquire, process and transfer data within residential or other types of buildings. This node is a tiny box calling up the data from switches, sensors and utility meters (Fig. 3) then preparing them for further processing. The data are stored and evaluated as a means of monitoring status and observing trends.



IMMS

By the linking up of individual items of information, many applications can be used at one and the same time on the system node, such as intelligent water leakage alarms. There are inter- and intra-building applications which can be used in conjunction with the SHS node and a server on the Internet to enable energy optimisation of wider heating systems or broader monitoring of building status.

Because of its expertise in energy efficiency, complex embedded systems and open source solutions, IMMS took responsibility for the development of the platforms (hardware and software) for the SHS node. The crucial specifications (which have to date by no means been fulfilled in a single system) were as follows.

- Maximum flexibility at the communication interfaces,
- Interoperability with existing automation and metering systems for buildings,
- Hardware with low energy use and high energy efficiency,
- Low cost for both hardware and software,
- Easy start-up and installation of the software for the application on the embedded platform.

All these requirements are met by the modular hardware and software platform that IMMS developed. There are extension boards to allow the interface to be expanded. The system software is robust and has all the basic functions necessary for the hardware and for any networking with other systems. The software framework simplifies the development of applications and their integration into upstream automation systems. The platform is accompanied by comprehensive documentation and development tools which will make it easy to operate and extend.

The base board (Fig. 2) contains a 600 MHz TI AM3505 microcontroller which, in turn, contains a highly efficient ARM Cortex A8 microprocessor core. All the standard interfaces (RS232, USB and Ethernet) are present and can be extended by any device boards necessary to the application, within the 10 cm x 16 cm housing. Extensions are available in the form of a Wireless M-Bus extension board and the smart home extension board (with digital I/Os, RS484, KNX, USB) from Bischoff Elektronik, partner in the project.

## Access to all information from smart phones, PCs and tablet PCs

User friendliness will always be crucial to public acceptance and successful use of systems like these. There are so many technical components included

Figure 1: Block of flats, Jena, with SHS demonstration system installed. Photograph: IMMS, System Design.

and settings required that intuitive graphics and operation are essential. It was a particular concern of IMMS to integrate the GUI seamlessly into the end user's familiar technological scene, so that a tenant will be able to access the SHS straight from his or her smart phone or tablet PC, and caretakers, whether on the spot or on their travels, will be able to interact with the building energy management systems from their laptops. Landlords, landladies and property managers will be able to interact with the SHS comfortably from their office desks via PC and Internet. IMMS has also taken account of the needs of particular groups by providing customized interfaces and menus (Fig 4.).

## A flexible, adaptable service platform with open source software

The Institute has laid the full software basis to enable future developers to exploit SHS potential in its fullest possible way. This basis is a Linux operating system optimized by IMMS for this purpose. It enables the hardware on which it is installed to be run with maximum energy savings, even for applications that require realtime capabilities. The base board consumes only 1 Watt (approximately) and at full load within the network it runs on only 1.7 Watts. No solution with comparable performance has achieved such low energy consumption to date. The absence of licence costs and low investment risk associated with Linux (which never involves notice of expiry) are economic advantages speaking loudly in its favour.

Figure 2: Base board of the SHS system node. Photograph: IMMS.

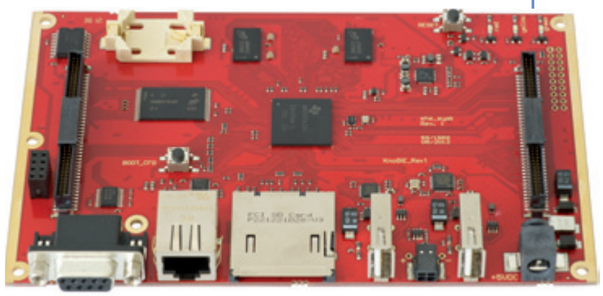



Figure 3: Wireless water and heating meters and a smart meter gateway. Photograph: IMMS, System Design.

C++ is the basic language of the software framework constituting the actual service platform, which draws on Qt, an open source library, and uses D-Bus (also open source) for interprocess communication. As web technology is the choice throughout, the user interface for the SHS node is extremely flexible. The web server is embedded and scripting languages available to developers are Python, JavaScript and QtScript.

## Demonstration system applied jointly with Thüringen housing association

A number of Thüringen development partners for the SHS project have cooperated to install a prototype Smart Home System in certain blocks of flats together with the individual flats in Jena (Fig. 1). The partners are Bischoff Elektronik and Kirchhoff Datensysteme, users in the housing sector and IMMS. The demonstration system has already been handed over to its users. It enables not only the tenants to test out the home services of the building energy management system, but also the landlords and property owners. An instance of the application is a check for the risk of mould in critical walls or a remote check on whether the doors and windows are closed. The property manager, too, will have remote access to the central building controls and thus be able to get information automatically if technical problems have arisen. Critical points in the building as regards humidity, temperature distribution and energy consumption can be identified and the energy use managed optimally in the entire building. Users can operate the system and call up the data via the Internet or directly from their in-flat PC, smart phone or tablet.

## Technical foundations for new applications

The development will be susceptible to much wider use beyond that of the SHS building energy management system. The high performance and flexibility of both the hardware and software will mean the system can be used in instances such as industrial process control or traffic and environmental monitoring systems. IMMS is already working together with research and industrial partners on these potential applications.

This project was completed in 2012 and saw IMMS successfully applying and extending its knowledge of complex embedded systems. In the course of the research into energy-efficient hardware platforms and flexible software frameworks, the institute obtained results which will be usable in wide reaching applications. They will lay the foundation for more projects, such as “S4ECoB”, an EU research project to which IMMS is contributing its knowledge and skills and in which energy efficiency in buildings is improved in yet more ways.

**Contact:**
Dipl.-Ing. Wolfram Kattanek
wolfram.kattanek@imms.de

**Bibliography:**

1 Christian Kellner, Frank Schnellhardt, Gunnar Weiß, Tobias Werner: SHS – SmartHomeService-Lösung für die Wohnungswirtschaft, In: Intelligent Wohnen : Zusammenfassung der Beiträge zum Usability Day IX, 20. Mai 2011 (2011), S. 61 – 69.

IMMS published several papers in 2012 on this subject – cf. no. 2, 5, 29, 32, 38 and 50 in the publictions list, p. 49ff.

Figure 4: Smartphone and tablet with mould warning service and automatic lighting service. Photograph: IMMS, System Design.

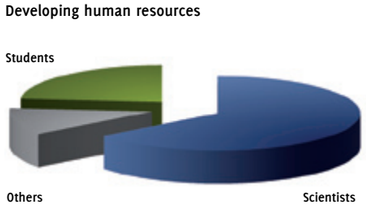


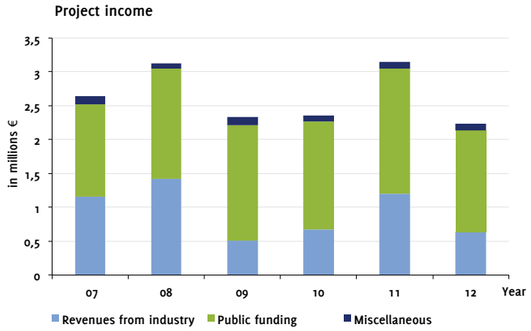
IMMS

# PROOF THROUGH FACTS AND FIGURES

Test setup in the cleanroom of the IMMS premises, Erfurt. Photograph: IMMS.

# Facts and figures 2012



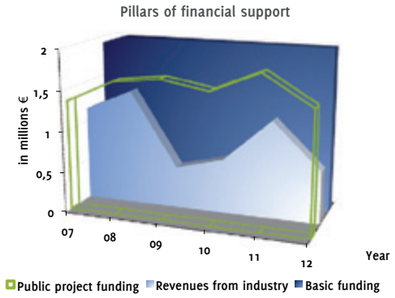

2012 saw 91 members of staff working at IMMS. 57 were scientists employed and 22 were students, all involved on research and development, which constituted 87% of the entire staff.

As in all recent years, the number of students availing themselves of the opportunities at IMMS to pursue research of relevance to real life was high. Ten of them came on internships and the Institute's staff supervised nine BSc and MSc dissertations. There are five IMMS researchers currently pursuing doctoral studies at various universities. IMMS makes a point of engaging in undergraduate teaching in order to be able to attract enough of the highest quality graduates.

Income from industrial research commissions was about 50% less than that of the previous year and the income from public funding about 20% less. The main significant factors were, firstly, serious delays in the approval processes for publicly funded projects, over which IMMS has no control. Secondly, 2012 was a year distinguished by great caution on the part of IMMS' industrial partners in the matter of outsourcing their research and development. The world economic crisis had brought it about that companies not only became more frugal but also spent more time and resources on internal research. The result for IMMS was a backlog of work at the start of 2013.

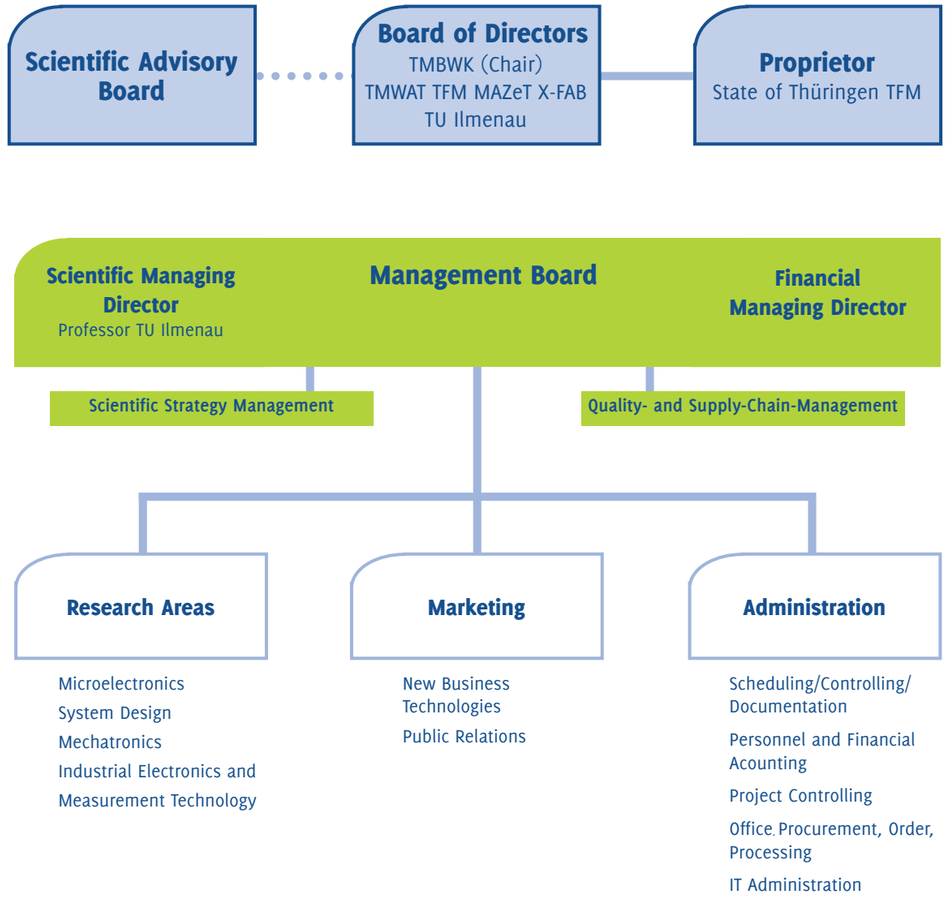
Though income in 2012 was lower, the picture is still of very pleasing developments in financial support for IMMS projects, almost all of which are joint with other partners. This is evidence of how well IMMS is accepted in the research partner role. The Institute has succeeded in achieving increased project activity by getting involved in research networks. Now it must meet the challenge of holding this position in respect of project funding and making progress on the acquisition of industrial commissions. Earnings from these go a long way to helping finance the less than generously funded public endeavours.

Thüringen as federal 'Land' maintained its level of support in 2012 to keep the Institute on an even keel. The work IMMS could do for regional SMEs benefited above all from this, but there is no longer any compensation for pay rises and inflation.






# Organigram



## Scientific Advisory Board

**Chairman:** Prof. Dr. CHRISTIAN BRECHER, Director of the Institute WZL of the RWTH Aachen, Research Area Machine Tools

**Assistant Chairman:** OLAF MOLLENHAUER, Managing Partner TETRA GmbH, Ilmenau

**Honorary Member:** Prof. Dr. habil. EBERHARD KALLENBACH, Director of Steinbeis-Transferzentrum Mechatronik, Ilmenau

Prof. Dr. ERICH BARKE, President Leibniz Universität Hannover, Faculty Computer Science

Dr. HERWIG DÖLLEFELD, Innovation Manager, X-FAB Semiconductor Foundries AG, Erfurt *(to 24/02/2012)*

Dr.-Ing. GABRIEL KITTLER, Innovation Manager, X-FAB Semiconductor Foundries AG, Erfurt *(since 12/10/2012)*

Prof. Dr. GÜNTER ELST, in retirement, formerly Fraunhofer-Institut für Integrierte Schaltungen IIS – EAS, Director of the Instituts branch Entwurfsautomatisierung EAS, Dresden

Dr. FRED GRUNERT, Technical Director MAZeT GmbH, Jena

Prof. Dr. habil. MATTHIAS HEIN, Ilmenau University of Technology, RF and Microwave Research Laboratory

Prof. Dr. OLFA KANOUN, Chemnitz University of Technology, Pro-Dean Faculty Electrical and Information Engineering, Chair Measuring and Sensor Technology

Dr. NORBERT LENK, Director AJ IDC Geräteentwicklungsgesellschaft mbH Langewiesen, a company of Analytik Jena AG

Dr. MICHAEL TRUTZEL, Senior Director Technology, Carl Zeiss Jena GmbH, Jena

Prof. Dr. ANDREAS TÜNNERMANN, Scientific Director Friedrich Schiller University Jena, Chair Applied Physics

## Board of Directors

**Chairman:** Dr. JÖRG PRINZHAUSEN, Thuringia Ministry of Education, Science and Culture

**Assistant Chairman:** Dr. FRANK EHRHARDT, Ministry of Economy, Technology and Labour Thüringen

Univ. Prof. Dr.-Ing. KLAUS AUGSBURG, Prorector Science, Ilmenau University of Technology, Faculty Mechanical Engineering

Dr. ERICH HACKER, PolymerMat e.V., Plastic material cluster Thüringen *(to 28/08/2012)*

Dr. sc. WOLFGANG HECKER, Director, MAZeT GmbH, Jena

Dr. JENS KOSCH, Chief Technical Officer, X-FAB Semiconductor Foundries AG

THOMAS WEISSENBORN, Ministry of Finance Thüringen



IMMS

## Lectures, lecture Series

**Prof. Dr. Ralf Sommer**

**"Grundlagen der Schaltungstechnik"** ("Fundamentals of Circuit Design"), lecture and tutorial, Ilmenau University of Technology, Department Electronic Circuits and Systems, bachelor students, 3rd semester

**"Rechnergestützte Entwurfsmethodik (EDA) für Analog/Mixed-Signal-Schaltungen"** ("Computer Aided Design Methodology and EDA for analog / mixed-signal circuits"), lecture and tutorial, Ilmenau University of Technology, Department Electronic Circuits and Systems, bachelor students, 6th semester

**Dr. Eckhard Hennig**

**"Modellierung und Simulation analoger Systeme"** ("Modeling and simulation of analog systems"), lecture and tutorial, Ilmenau University of Technology, Department Electronic Circuits and Systems, bachelor students, 5th semester

**Eric Schäfer, M.Sc.**

**"Modellierung und Simulation von Delta-Sigma-ADCs"** ("Modeling and simulation of delta/sigma ADCs"), lecture and tutorial, Ilmenau University of Technology, Department Electronic Circuits and Systems, bachelor students, 5th semester

**Dr. Christoph Schäffel**

**"Entwicklung technischer Produkte"** ("Development of technological products"), lecture in the context of the lecture series, Ilmenau University of Technology, Institute for Physics, students of the Institute for Physics

**Dr. Wolfgang Sinn**

**"Sensorik"** ("Sensor technology"), lecture, Berufsakademie (Thüringen's University of Co-operative Education) in Eisenach, field of study Mechatronics and Automation, bachelor students, supervision for four bachelor's theses

**Dipl.-Ing. Sven Engelhardt**

**"Automatisierungssysteme"** ("Automation systems"), lecture and tutorial, Berufsakademie (Thüringen's University of Co-operative Education) in Eisenach, field of study Construction, bachelor students

**"Mikrocontroller-Technik"** ("Microcontroller technology"), tutorials, Berufsakademie (Thüringen's University of Co-operative Education) in Eisenach, field of study Construction and Technical Management, bachelor students

## Publications 2012

### Papers


1. Sebastian SCHEIBE, Josepha DARGEL, Reichweitenmessung drahtloser Sensormodule als Basis energieoptimaler Netzwertopologien, Power and Energy Student Summit 2012, Ilmenau, Germany, Tagungsband, S. 14-17, urn:nbn:de:gbv:ilm1-2012200042

2. Elena CHERVAKOVA[1], Wolfram KATTANEK[1], Ulf KNOBLICH[2], Michael BINHACK[3], Added-Value Services in Smart Home Applications through System Integration of Different Wireless Standards, embedded world conference, Haar: Weka Fachmedien, ISBN 978-3-645-50072-2, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]AMBER wireless GmbH, Germany, Köln, [3]senTec Elektronik GmbH, Germany, Ilmenau

3. Gregor NITSCHE, Georg GLÄSER, Eckhard HENNIG, Hardware/Software Co-Design of a Smart Sensor Interface using a Fast but Accurate Close-to-RTL Instruction Set Interpreter, in Methoden und Beschreibungssprachen zur Modellierung in Verifikation von Schaltungen und Systemen – MBMV 2012 (Hrsg: Jens Brandt und Klaus Schneider), Schriftenreihe Forschungsergebnisse zur Informatik, Band 68, Verlag Dr. Kovac, Hamburg, 2012, S. 121-132

4. Nikola BASTA[1], Achim DREHER[1], Stefano CAIZZONE[1], Matteo SGAMMINI[1], Felix ANTREICH[1], Safwat IRTEZA[2], Ralf STEPHAN[2], Matthias A. HEIN[2], Eric SCHÄFER[3], André RICHTER[3], Muhammad Abdullah KHAN[3,] Lothar KURZ[4], Tobias G. NOLL[4], System Concept of a Compact Multi-Antenna GNSS Receiver, 7th German German Microwave Conference (GeMiC), 2012, http://ieeexplore.ieee.org, IEEE Xplore Digital Library, E-ISBN 978-3-9812668-4-9, [1]German Aerospace Center (DLR) Institute for Communication and Navigation, Germany, [2]RF and Microwave Laboratory, University of Technology Ilmenau, Germany, [3]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [4]Chair of Electrical Engineering and Computer Science, RWTH Aachen University, Germany

**5.** Marco GÖTZE, Wolfram KATTANEK, Rolf PEUKERT, An Extensible Platform for Smart Home Services, 9th International Multi-Conference on Systems, Signals and Devices (SSD), 2012, http://ieeexplore.ieee.org, IEEE Xplore Digital Library, Digital Object Identifier: 10.1109/SSD.2012.6198110, E-ISBN 978-1-4673-1589-0

**6.** Michael MEISTER, Marco REINHARD, Ullrich LIEBOLD, Dagmar KIRSTEN, Dirk NUERNBERGK, Critical optical power density in PIN-Photodiodes, 9th International Multi-Conference on Systems, Signals and Devices (SSD), 2012, http://ieeexplore.ieee.org, IEEE Xplore Digital Library, Digital Object Identifier: 10.1109/SSD.2012.6197902, E-ISBN 978-1-4673-1589-0

**7.** Björn BIESKE[1], Klaus HEINRICH[2], Developing and Testing RF modules in CMOS for ISM and SRD Bands using PXI platform, 9th International Multi-Conference on Systems, Signals and Devices (SSD), 2012, http://ieeexplore.ieee.org, IEEE Xplore Digital Library, Digital Object Identifier: 10.1109/SSD.2012.6197945, E-ISBN 978-1-4673-1589-0, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]X-FAB Semiconductor Foundries AG, Germany, Erfurt

**8.** Björn BIESKE, Alexander ROLAPP, Testing symmetrical 2.4 GHz ZigBee Transceivers using unsymmetrical RF Measurement Equipment, 9th International Multi-Conference on Systems, Signals and Devices (SSD), 2012, http://ieeexplore.ieee.org, IEEE Xplore Digital Library, Digital Object Identifier: 10.1109/SSD.2012.6197944, E-ISBN 978-1-4673-1589-0

**9.** R. GRIESELER[1], J. KLAUS[2], M. STUBENRAUCH[3], K. TONISCH[3], S.MICHAEL[2], J. PEZOLDT[3] & P. SCHAAF[1], Residual stress measurements and mechanical properties of AlN thin films as ultra-sensitive materials for nanoelectromechanical systems, Philosophical Magazine, Special Issue: Nano-mechanical testing in materials research and development III, Volume 92, Issue 25-27, 2012, Pages 3392-3401, http://dx.doi.org/10.1080/14786435.2012.669074 , [1]Materials for Electronics Group, Institute of Micro- and Nanotechnologies MacroNano® and Institute of Materials Engineering, Ilmenau University of Technology, Germany, [2]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [3]Nanotechnology Group, Institute of Micro- and Nanotechnologies MacroNano® and Institute of Micro- and Nanoelectronics, Ilmenau University of Technology, Germany

**10.** Björn BIESKE[1], Klaus HEINRICH[2], Test von HF-Zellen – Auf Basis modularer PXI-Testsysteme, Elektronik Industrie, 5.2012, S. 62-64, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]X-FAB Semiconductor Foundries AG, Germany, Erfurt

**11.** Komla AGLA[1], Olaf WETZSTEIN[2], Thomas ORTLEPP[3], Hannes TÖPFER[1,4], Analyse des rauschinduzierten Timing-Jitters in Low-Power Mixed-Signal-Schaltungen mittels einer High-Level Beschreibung, Dresdner Arbeitstagung Schaltungs- und Systementwurf (DASS), 2012, Tagungsband, ISBN 978-3-8396-0404-5, CD-ROM, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Institut für Photonische Technologien (IHPT) Jena, Abteilung Quantendetektion, [3]University of California Berkeley, Department of Electrical Engineering and Computer Science, Berkeley USA, [4]Technische Universität Ilmenau, Fachgebiet Theoretische Elektrotechnik, Germany, Ilmenau

**12.** C. RUDOLF[1], C. MOCK[1], C. WALENDA[1], R. GLÖSS[1], R. LIANG[1], C. SCHÄFFEL[2], M. KATZSCHMANN[2], H.-U. MOHR[2], 6D Magnetic Levitation Positioning System with Compact Integrated 6D Sensor, 12th EUSPEN International Conference, in Proceedings P7.04 Vol II, ISBN 978-0-9566790-0-0, [1]Physik Instrumente (PI) GmbH & Co. KG, Germany, Karlsruhe, [2]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau

**13.** Steffen HESSE[1], Christoph SCHÄFFEL[1], Hans-Ulrich MOHR[1], Michael KATZSCHMANN[1], Hans-Joachim BÜCHNER[2], Design and performance evaluation of an interferometric controlled planar nanopositioning system, in Measurement Science and Technology, 23 (2012) 074011 (10pp), http://stacks.iop.org/0957-0233/23/074011, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Institut für Prozessmess- und Sensortechnik, Technische Universität Ilmenau, Germany

**14.** Rainer GLÖSS[1], Christopher MOCK[1], Christian RUDOLF[1], Carolin WALENDA[1], Christoph SCHÄFFEL[2], Michael KATZSCHMANN[2], Hans-Ulrich MOHR[2], Magnetic Levitation in 6DOF with Halbach array Configuration, Actuator, International Conference and Exhibition on New Actuators and Drive Systems, in Proceedings, ISBN 978-3-933339-20-1, CD-ROM, [1]Physik Instrumente (PI) GmbH & Co. KG, Germany, Karlsruhe, [2]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau

**15.** Volker BOOS, EDADB-Tools for semi-automatic Technology Porting of Integrated Mixed-Signal Circuits, Access to research results on semiconductor design, Internet-Platform - RD-Access, https://www.rd-access.eu/edatools/show/designtools, 04.09.2012

**16.** H. MEHNER[1], K. BRUECKNER[1], D. KAROLEWSKI[2], S. MICHAEL[2], M. A. HEIN[1], M. HOFFMANN[1], Stress Controlled Piezoelectric ALN-MEMS-Resonators with Molybdenum Electrodes for GHz Application, 23rd Micromechanics and Microsystems Europe Workshop (MME), 2012, in Proceedings, Session C.06, online: https://www.tu-ilmenau.de/fileadmin/media/mme2012/Proceedings/Session_C/C06_1642_MME2012_120622.pdf, [1]Institute of Micro- and Nanotechnologies MacroNano®, University of Technology Ilmenau, Germany, [2]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau

**17.** Achim DREHER[1], Nikola BASTA[1], Stefano CAIZZONE[1], Götz KAPPEN[1], Matteo SGAMMINI[1], Michael MEURER[1], Safwat I. BUTT[2], Ralf STEPHAN[2], Matthias A. HEIN[2], Eric SCHÄFER[3], Muhammad A. KHAN[3], André RICHTER[3], Björn BIESKE[3], Lothar KURZ[4], Tobias G. NOLL[4], Compact Adaptive Multi-antenna Navigation Receiver, ION GNSS, 2012, in Proceedings, Pages 917-925, online: http://www.ion.org/search/browseDetail.cfm?id=67, [1]German Aerospace Center (DLR), Institute for Communication and Navigation, Germany, [2]RF and Microwave Laboratory, University of Technology Ilmenau, Germany, [3]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [4]Chair of Electrical Engineering and Computer Science, RWTH Aachen University, Germany

**18.** Muralikrishna SATHYAMURTHY[1], Felix NEUMANN[1], Lukasz KOTYNIA[2], Eckhard HENNIG[1], Ralf SOMMER[1], UVM-based Verification of Smart-Sensor Systems, International Conference on Synthesis, Modeling, Analysis and Simulation Methods and Applications to Circuit Design (SMACD), 2012, http://ieeexplore.ieee.org, IEEE Xplore Digital Library, Digital Object Identifier: 10.1109/SMACD.2012.6339407, ISBN 978-1-4673-0685-0, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Technical University of Lodz, Poland

**19.** Komla AGLA[1], O. WETZSTEIN[2], T. ORTLEPP[3], Hannes TÖPFER[4], Modeling of noise-induced jitter in lower-power mixed-signal circuits using a high-level description, 20th Telecommunications Forum (TELFOR), 2012, http://ieeexplore.ieee.org, IEEE Xplore Digital Library, Digital Object Identifier : 10.1109/TELFOR.2012.6419364, ISBN 978-1-4673-2983-5, Pages 943 – 946, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Institut für Photonische Technologien (IHPT) Jena, Abteilung Quantendetektion, Germany [3]University of California Berkeley, Department of Electrical Engineering and Computer Science, Berkeley USA, [4]Technische Universität Ilmenau, Fachgebiet Theoretische Elektrotechnik, Germany, Ilmenau

**20.** Christoph SCHÄFFEL[1], Michael KATZSCHMANN[1], Hans-Ulrich MOHR[1], Rainer GLÖSS[2], Christian RUDOLF[2], Christopher MOCK[2], Carolin WALENDA[2], R. LIANG[2], Planar Magnetic 6D Levitating system with Compact Sensor, 27th Annual Meeting of the American Society for Precision Engineering (ASPE), 2012, in Proceedings, ISBN 978-1-887706-61-2, Pages 99-102, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Physik Instrumente (PI) GmbH & Co. KG, Germany, Karlsruhe

**21.** Steffen HESSE[1], Christoph SCHÄFFEL[1], Michael KATZSCHMANN[1], Hans-Joachim BÜCHNER[2], Positioning performance of a planar nanopositioning system with 100 mm circular travel range, 27th Annual Meeting of the American Society for Precision Engineering (ASPE), 2012, in Proceedings, ISBN 978-1-887706-61-2, Pages 103-106, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Institut für Prozessmess- und Sensortechnik, Technische Universität Ilmenau, Germany, Ilmenau

**22.** Mario EIFART[1], Elena CHERVAKOVA[1], Wolfram KATTANEK[1], Ralf ZENKER[2], Energieoptimaler Betrieb von drahtlosen Condition Monitoring Systemen, 22. IWK Mittweida, in Journal Scientific Reports der Hochschule Mittweida, ISSN 1437-7624, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Technische Universität Dresden, Fakultät Informatik, Institut für Angewandte Informatik, Germany, Dresden

**23.** Silvia KRUG, Strategie zur Laufzeitverlängerung von Routern in 6Lowpan-Sensornetzwerken unter Berücksichtigung von Quality-of-Service Parametern, 22. IWK Mittweida, in Journal Scientific Reports der Hochschule Mittweida, ISSN 1437-7624

## Presentations and posters

**24.** Safwat IRTEZA[1], Eric SCHÄFER[2], Christian VOLMER, Matteo SGAMMINI[3], Ralf STEPHAN[1], Eckhard HENNIG[2], Matthias A. HEIN[1], Noise Characterization of a Multi-Channel Receiver Using s Small Antenna Array with Full Diversity for Robust Sattelite Navigation, IEEE International Conference on Wireless Information Technology and Systems (ICWITS), 2012, http://ieeexplore.ieee.org, IEEE Xplore Digital Library, Digital Object Identifier: 10.1109/ICWITS.2012.6417676, ISBN: 978-1-4673-0947-9, [1]RF and Microwave Laboratory, University of Technology Ilmenau, Germany, [2]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [3]German Aerospace Center (DLR), Institute for Communication and Navigation, Germany

**25.** Peter KORNETZKY, Martin SACHS, Stefan SCHRAMM, Realisierbarkeit eines tragbaren Erfassungssystems für leitungsgebundene Störströme in Industrieanlagen, Deutsche Gesellschaft für die Anwendung der Mikroelektronik e.V. (DFAM), Studie Nr. 8/2012, ISBN 978-3-8163-0622-1

**26.** Ralf SOMMER[1], Eckhard HENNIG[1], Gregor NITSCHE[1], J. BROZ, P. SCHWARZ, Automatic Nonlinear Behavioral Model Generation Using Symbolic Circuit Analysis, in Design of Analog Circuits through Symbolic Analysis, M. Fakhfakh, E. Tlelo-Cuautle, and F. V. Fernández, Eds., Bentham Science Publishers, 2012, ch. 12, Pages 305-341, http://www.eurekaselect.com/101990/volume/1, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau

**27.** Ralf SOMMER[1,2], Dominik KRAUSSE[2], Eric SCHÄFER[1], Eckhard HENNIG[1], Application of Symbolic Circuit Analysis for Failure Detection and Optimization of Industrial Integrated Circuits, in Design of Analog Circuits through Symbolic Analysis, M. Fakhfakh, E. Tlelo-Cuautle, and F. V. Fernández, Eds., Bentham Science Publishers, 2012, ch. 17, Pages 445-477, http://www.eurekaselect.com/101990/volume/1, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Technische Universität Ilmenau, Fachgebiet Elektronische Schaltungen und Systeme, Ilmenau, Germany

**28.** Sebastian SCHEIBE, Josepha DARGEL, Reichweitenmessung drahtloser Sensormodule als Basis energie-optimaler Netzwertopologien, Power and Energy Student Summit 2012, Ilmenau, 19.01.2012-20.01.2012

**29.** Elena CHERVAKOVA[1], Wolfram KATTANEK[1], Ulf KNOBLICH[2], Michael BINHACK[3], Added-Value Services in Smart Home Applications through System Integration of Different Wireless Standards, embedded world conference, Nürnberg, 28.02.2012-01.03.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]AMBER wireless GmbH, Germany, Köln, [3]senTec Elektronik GmbH, Germany, Ilmenau

**30.** Gregor NITSCHE, Georg GLÄSER, Eckhard HENNIG, HW/SW-Co-Entwurf einer intelligenten Sensor-Schnittstelle mit Hilfe eines schnellen, Zyklenzahl-genauen, RTL-nahen Befehlssatz-Simulators, 15. Workshop Methoden und Beschreibungssprachen zur Modellierung und Verifikation von Schaltungen und Systemen (MBMV), 2012, Kaiserslautern, 05.03.2012-07.03.2012

**31.** R. GRIESELER[1], K. TONISCH[2], J. KLAUS[3], M. STUBENRAUCH[2,] B. LEISTRITZ[3], R. SRNÁNEK[4], S. MICHAEL[3], J. PEZOLDT[2], P. SCHAAF[1], Ultrasensitive Materialien für Nanoelektromechanische Systeme – USENEMS, Thüringer Werkstofftag, 2012, Weimar, 14.03.2012, [1]Materials for Electronics Group, Institute of Micro- and Nanotechnologies MacroNano® and Institute of Materials Engineering, Ilmenau University of Technology, Germany, [2]Nanotechnology Group, Institute of Micro- and Nanotechnologies MacroNano® and Institute of Micro- and Nanoelectronics, Ilmenau University of Technology, Germany, [3]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [4]Fachgebiet für Mikroelektronik, FEI Slowakische Technische Universität Bratislava, Slowakei

**32.** Marco GÖTZE, Wolfram KATTANEK, Rolf PEUKERT, An Extensible Platform for Smart Home Services, 9th International Multi-Conference on Systems, Signals and Devices (SSD), 2012, Chemnitz, 20.03.2012-23.3.2012

**33.** Michael MEISTER, Marco REINHARD, Ullrich LIEBOLD, Dagmar KIRSTEN, Dirk NUERNBERGK, Critical optical power density in PIN-Photodiodes, 9th International Multi-Conference on Systems, Signals and Devices (SSD), 2012, Chemnitz, 20.03.2012-23.3.2012

**34.** Björn BIESKE[1], Klaus HEINRICH[2], Developing and Testing RF modules in CMOS for ISM and SRD Bands using PXI platform, 9th International Multi-Conference on Systems, Signals and Devices (SSD), 2012, Chemnitz, 20.03.2012-23.3.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]X-FAB Semiconductor Foundries AG, Germany, Erfurt

**35.** Björn BIESKE, Alexander ROLAPP, Testing symmetrical 2.4 GHz ZigBee Transceivers using unsymmetrical RF Measurement Equipment, 9th International Multi-Conference on Systems, Signals and Devices (SSD), 2012, Chemnitz, 20.03.2012-23.3.2012

**36.** Ralf ZENKER[1], Wolfram KATTANEK[2], Energieeffiziente Sensornetze zum akustischen Monitoring, Cyber-physikalische Systeme - Chancen für neue energieeffiziente Anwendungen, Fachworkshop Applikationen, Dresden, 29.03.2012-30.03.2012, [1]Technische Universität Dresden, Fakultät Informatik, Institut für Angewandte Informatik, [2]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau

**37.** Wolfgang SINN, Vernetzt, mobil, smart - Bausteine für CPS, Cyber-physikalische Systeme - Chancen für neue energieeffiziente Anwendungen, Fachworkshop Applikationen, Dresden, 29.03.2012-30.03.2012

**38.** Tino HUTSCHENREUTHER, Marco GÖTZE, Wolfram KATTANEK, Smart Home Platform for the Integration of Image Information in Daily Life Situations, 13. SpectroNet Collaboration Forum, Konstanz, 17.04.2012

**39.** R. GRIESELER[1], K. TONISCH[2], J. KLAUS[3], M. STUBENRAUCH[2], S. MICHAEL[3], J. PEZOLDT[2], P. SCHAAF[1], Testing of mechanical properties of AlGaN thin films by Eigenmode detection on Microelectromechanical Systems (MEMS), Int. Conference on Metallurgical Coating and Thin Films, ICMCTF, San Diego, USA, 23.04.2012-27.04.2012, [1]Materials for Electronics Group, Institute of Micro- and Nanotechnologies MacroNano® and Institute of Materials Engineering, Ilmenau University of Technology, Germany, [2]Nanotechnology Group, Institute of Micro- and Nanotechnologies MacroNano® and Institute of Micro- and Nanoelectronics, Ilmenau University of Technology, Germany, [3]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau

**40.** Komla AGLA[1], Olaf WETZSTEIN[2], Thomas ORTLEPP[3], Hannes TÖPFER[1,4], Analyse des rauschinduzierten Timing-Jitters in Low-Power Mixed-Signal-Schaltungen mittles einer High-Level Beschreibung, Dresdner Arbeitstagung Schaltungs- und Systementwurf (DASS), 2012, Dresden, 03.05.2012-04.05.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Institut für Photonische Technologien (IHPT) Jena, Abteilung Quantendetektion, Germany, [3]University of California Berkeley, Department of Electrical Engineering and Computer Science, Berkeley USA, [4]Technische Universität Ilmenau, Fachgebiet Theoretische Elektrotechnik, Germany, Ilmenau

**41.** Muralikrishna SATHYAMURTHY[1], Eckhard HENNIG[1], Felix NEUMANN[2], A UVM-based Verification Methodology for RFID-enabled Smart Sensor Systems, CDNLive!, Cadence User Conference, EMEA 2012, München, 14.5.2012-16.05.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Technische Universität Ilmenau, Fachgebiet Elektronische Schaltungen und Systeme, Germany, Ilmenau

**42.** Muralikrishna SATHYAMURTHY[1], Eckhard HENNIG[1], Felix NEUMANN[2], Lukasz KOTYNIA[3], Early Power Estimation in a Mixed-Signal Environment using UVM and RTL Compiler, CDNLive!, Cadence User Conference EMEA 2012, München, 14.5.2012-16.05.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Technische Universität Ilmenau, Fachgebiet Elektronische Schaltungen und Systeme, Germany, Ilmenau, [3]Department of Microelectronics and Computer Science DMCS Technical University of Lodz, Poland

**43.** C. RUDOLF[1], C. MOCK[1], C. WALENDA[1], R. GLÖSS[1], R. LIANG[1], C. SCHÄFFEL[2], M. KATZSCHMANN[2], H.-U. MOHR[2], 6D Magnetic Levitation Positioning System with Compact Integrated 6D Sensor, 12th EUSPEN Int. Conference, Schweden, Stockholm, 04.06.2012-08.06.2012, [1]Physik Instrumente (PI) GmbH & Co. KG, Germany, Karlsruhe, [2]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau

**44.** Wolfgang SINN, Logistik – von der Via Regia zu vernetzten Welten, erwicon, Erfurter Wirtschaftskongress, Erfurt, 07.06.2012-08.06.2012

**45.** Christoph SCHÄFFEL[1], Rainer GLÖSS[2], Magnetisch schwebende Plattform zur nm-Positionierung, Technologiekonferenz, elmug4future, Suhl, 26.06.2012-27.06.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Physik Instrumente (PI) GmbH & Co. KG, Germany, Karlsruhe

**46.** Wolfgang SINN, Vernetzt, mobil, smart – Märkte der Zukunft, Technologiekonferenz, elmug4future, Suhl, 26.06.2012-27.06.2012

**47.** Wolfgang SINN, Vernetzt, mobil, smart – Herausforderungen an die Mikroelektronik, 7. Silicon Saxony Day "Vernetzt in die Zukunft", Dresden, 27.06.2012

**48.** Wolfgang SINN, Trends in der Sensortechnologie – Einsatz der Sensorik für die Qualitätssicherung, Treffen des Regionalkreises Erfurt der Deutschen Gesellschaft für Qualität (DGQ), Ilmenau, 06.07.2012

**49.** Wolfram KATTANEK, Praktische Aspekte der Gestaltung von drahtlosen Sensornetzwerken, Institutskolloquium des Instituts für Informationstechnik der Technische Universität Ilmenau, Ilmenau, 11.07.2012

**50.** Wolfram KATTANEK, Energieeffizienzaspekte eingebetteter IKT-Komponenten, 57. Internationales Wissenschaftliches Kolloquium (IWK) der TU Ilmenau, Ilmenau, 03.09.2012-07.09.2012

**51.** Bianca LEISTRITZ[1,2], Stefan HAMPL[1,3], Eckhard HENNIG[1], Energy harvesting from low-frequency motions in the single-digit Hertz range, 57. Internationales Wissenschaftliches Kolloquium (IWK) der TU Ilmenau, Ilmenau, 03.09.2012-07.09.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Technische Universität Ilmenau, Fachgebiet Theoretische Elektrotechnik, Germany, Ilmenau, [3]Technische Universität Ilmenau, IMN MacroNano®, FG Mikromechanische Systeme, Germany, Ilmenau

**52.** Eckhard HENNIG, Low-Power-Schaltungstechnik für energieeffiziente Sensorik, 57. Internationales Wissenschaftliches Kolloquium (IWK) der TU Ilmenau, Ilmenau, 03.09.2012-07.09.2012

**53.** Muralikrishna SATHYAMURTHY[1], Felix NEUMANN[1], Lukasz KOTYNIA[2], Eckhard HENNIG[1], Ralf SOMMER[1], UVM-based Verification of Smart-Sensor Systems, International Conference on Synthesis, Modeling, Analysis and Simulation Methods and Applications to Circuit Design (SMACD), 2012, Seville, Spain, 19.09.2012-21.09.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Technical University of Lodz, Poland

**54.** R. SOMMER[1], M. MEINERS[2], H. GRAEB[3], Schematic Driven MEMS Design, in Proc. (IEEE-Explorer) 10th International Workshop on Symbolic and Numerical Methods, Modeling and Applications to Circuit Design (SMACD'12), Seville, Spain, 19.09.2012-21.09.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Robert Bosch GmbH, Automotive Electronics, Reutlingen, Germany, [3] Institute of Electronic Design Automation, Technical University of Munich, Germany

**55.** Nikola BASTA[1], Safwat IRTEZA[2], Eric SCHÄFER[3], Lothar KURZ[4], System Concept for a Compact Multi-Antenna GNSS Receiver, 2nd COST VISTA Workshop, Istanbul, Turkey, 20.09.2012-21.09.2012, [1]German Aerospace Center (DLR), Institute for Communication and Navigation, Germany, [2]RF and Microwave Laboratory, University of Technology Ilmenau, Germany, [3]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [4]Chair of Electrical Engineering and Computer Science, RWTH Aachen University, Germany

**56.** Stefan HAMPL, Bianca LEISTRITZ, Eckhard HENNIG, Energieversorgungsoptionen für autarke multimodale Smart-Sensoren, 16. Heiligenstädter Kolloquium, Heilbad Heiligenstadt, 24.-26.09.2012

**57.** Eckhard HENNIG, GreenSense – Grundlagentechnologien für ressourcen- und energieeffiziente intelligente Sensornetzwerke, Workshop Industrienahe Forschungsgruppen des TMWAT, Technische Universität Ilmenau, Ilmenau, 26.09.2012

**58.** Wolfgang SINN, Von der Sensorik zur Umwelterkennung – strategische Herausforderungen, 14. Leibniz-Konferenz "Sensorsysteme 2012", Lichtenwalde, 18.10.2012-19.10.2012

**59.** Christoph SCHÄFFEL[1], Michael KATZSCHMANN[1], Hans-Ulrich MOHR[1], Rainer GLÖSS[2], Christian RUDOLF[2], Christopher MOCK[2], Carolin WALENDA[2], R. LIANG[2], Planar Magnetic 6D Levitating system with Compact Sensor, 27th Annual Meeting of the American Society for Precision Engineering (ASPE), 2012, San Diego, USA, 21.10.2012-26.10.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Physik Instrumente (PI) GmbH & Co. KG, Germany, Karlsruhe

**60.** Steffen HESSE[1], Christoph SCHÄFFEL[1], Michael KATZSCHMANN[1], Hans-Joachim BÜCHNER[2], Positioning performance of a planar nanopositioning system with 100 mm circular travel range, 27th Annual Meeting of the American Society for Precision Engineering (ASPE), 2012, San Diego, USA, 21.10.2012-26.10.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Institut für Prozessmess- und Sensortechnik, Technische Universität Ilmenau, Germany, Ilmenau

**61.** Silvia KRUG, Strategie zur Laufzeitverlängerung von Routern in 6Lowpan-Sensornetzwerken unter Berücksichtigung von Quality-of-Service Parametern, 22. IWK Mittweida, 1. Mittweidaer Workshop "Drahtlose Sensor-Aktor-Netzwerke", Mittweida, 24.10.2012-25.10.2012

**62.** Christoph SCHÄFFEL[1], Michael KATZSCHMANN[1], Hans-Ulrich MOHR[1], Rainer GLÖSS[2], Christopher MOCK[2], Christian RUDOLF[2], Carolin WALENDA[2], Planar Magnetic 6D Levitating System with Compact Sensor, 6. Tagung "Feinwerktechnische Konstruktion", Dresden, 08.11.2012, [1]IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Germany, Ilmenau, [2]Physik Instrumente (PI) GmbH & Co. KG, Germany, Karlsruhe

**63.** Wolfgang SINN, Intelligente Lichtkonzepte – Handlungsfeld für "Cyber-physikalische Systeme", Workshop "Photonik/Optoelektronik/Licht-Anwendungen", FB Applikationen des Silicon Saxony e.V. und Cooptics/OptoNet e.V., Jena, 26.11.2012

**64.** Wolfgang SINN, Cyber-physikalische Systeme – Rahmenbedingungen und Chancen für einen Arbeitskreis im Silicon Saxony, Gründungsmeeting Arbeitskreis CPS, Dresden, 03.12.2012

**65.** Wolfgang SINN, Zukunftsprojekt Industrie 4.0 - Herausforderungen an RFID & Co., 6. Dresdner RFID-Symposium, Dresden, 06.12.2012-07.12.2012

**66.** Tino HUTSCHENREUTHER, UltraLowPower-Anforderungen an die Vernetzung von Sensoren, ELMUG-Branchentag, Ilmenau, 5.12.2012

**67.** Silvia KRUG, Einfluss von MAC-Protokollen auf Quality-of-Service Parameter in 6LoWPAN-Netzwerken, InIT-Seminar, TU Ilmenau, Ilmenau, 12.12.2012

## Patents

### Granted patents 2012

**68.** Juraj KLEIN, Elektronische Schaltung für einen Transimpedanzverstärker, DE 103 11 096

**69.** Christoph SCHÄFFEL, Torsten MAASS, Volker BORNMANN, Michael KATZSCHMANN, Vorrichtung zur planaren Positionierung von Werkstücken, DE 10 2008 025 138

### Disclosed patents 2012

**70.** Christoph SCHÄFFEL, Dominik KAROLEWSKI, Michael KATZSCHMANN, Amado WITTINGHAM, Volker BORNMANN, Gleichstromlinearantrieb mit einem einen permanenterregten Magnetkreis umfassenden Stator und einem eine bewegliche Spule umfassenden Läufer, DE 10 2011 051 020

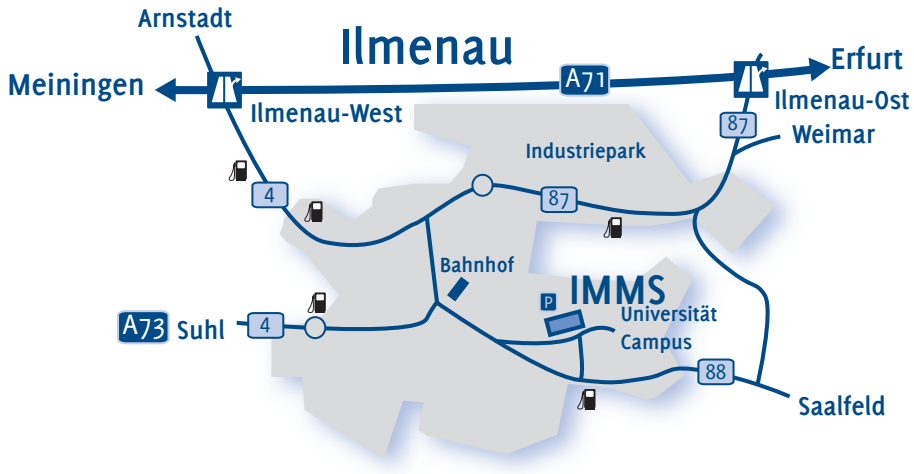
**71.** Christoph SCHÄFFEL, Michael KATZSCHMANN, Hans-Ulrich MOHR, Anordnung eines planaren 6D-Positionierers, Patentinhaber: Firma Physik Instrumente (PI) GmbH & Co.KG, Karlsruhe, DE 10 2011 100 153

**72.** Ralf SOMMER, Eric SCHÄFER, Dominik KRAUSSE, Eckhard HENNIG, Verfahren zur automatischen Topologiemodifikation beim Entwurf von analogen integrierten Schaltungen, DE 10 2011 113 421

## Other papers

**73.** Schlussbericht zur BMBF-Förderinitiative IKT 2020, Syntheseunterstützer Entwurf analoger Schaltungen (SyEnA), Teilvorhaben: Methoden zur automatisierten Generierung von optimierten analog/mixed-signal Schaltungen, Förderkennzeichen: 01 M 3086, Technische Informationsbibliothek, http://www.tib.uni-hannover.de

# Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH*




Ehrenbergstraße 27
D – 98693 Ilmenau, Thüringen, Germany

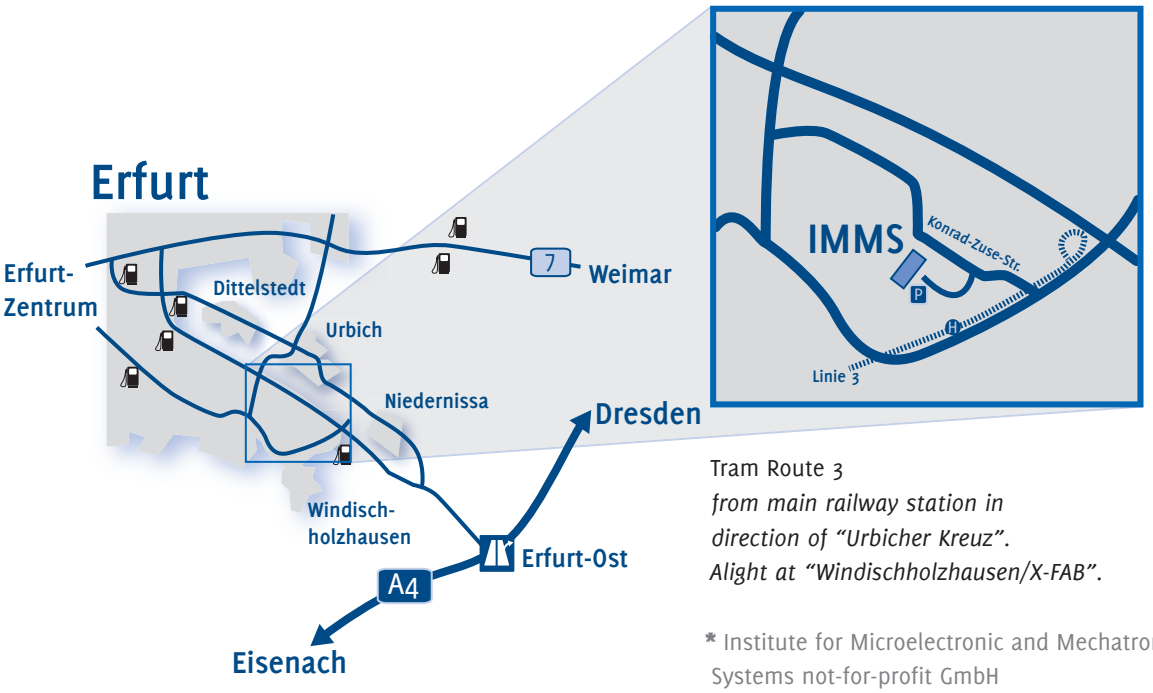
Tel.: +49.3677.6955.13
Fax: +49.3677.6955.15

E-Mail: imms@imms.de
www: http://www.imms.de

Branch office Erfurt:

Konrad-Zuse-Straße 14
99099 Erfurt, Thüringen, Germany

Tel.: +49.361.66325.00
Fax: +49.361.66325.01




Tram Route 3
*from main railway station in direction of "Urbicher Kreuz". Alight at "Windischholzhausen/X-FAB".*

* Institute for Microelectronic and Mechatronic Systems not-for-profit GmbH



IMMS