Lecture Notes in Mobility

Carolin Zachäus
Beate Müller
Gereon Meyer *Editors*

Advanced Microsystems for Automotive Applications 2017

Smart Systems Transforming the Automobile

EPoSS
European Technology Platform on Smart Systems Integration

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Preface

The ambitious goals of climate protection, energy efficiency, air quality, and road safety in combination with current trends in society and economy require restless innovation in sustainable and inclusive road transport solutions. Recent breakthroughs in electric and electronic components and systems, clean propulsion, automation, connectivity, IT-driven business models, and user-centric design promise viable opportunities for the automobile to meet those challenges.

However, it is foreseeable that additional principles will even further transform mobility in the next 5–10 years: Big data analysis, e.g., is already crucial for automation and will further enable cities to better respond to traffic issues, the Internet of Things will improve connected driving and together with blockchain facilitate mobility-as-a-service, robots and artificial intelligence will make human drivers obsolete not only in passenger cars but also potentially in all road vehicles, 3D printing will not only allow the production of novel vehicles but also change the demand for transport by making it possible to replace shipping products by shipping materials and local production, virtual and augmented reality may reduce the need to travel physically, and carbon fiber structures may make the automobile extremely lightweight and efficient. Moreover, maybe in 10–15 years, even more technical revolutions will arise not only creating completely new opportunities from integration and synergetic combinations of these various technologies with electrification, automation and sharing concepts that impact the demand for road transport but also widen the possibilities for road vehicles.

Currently, one of the main topics raising considerable attention of politicians and engineers alike are connected and automated vehicles and their enabling technologies. At the same time, governments are debating on the legal and infrastructural preconditions of automated driving and about how to harmonize the necessary investments. This field faces two major challenges.

First, R&I efforts need to be shifted from proof-of-concept to proof-of-reliability on the system level of automated driving technology. For instance, the performance envelope of sensors, data fusion, and object recognition systems has been pushed considerably in recent years, but does still not cover the complexity that a vehicle encounters in everyday life. Particularly for applications in urban environments and at higher levels of automation, perception of the driving environment is a challenging task to be mastered in a robust fashion. Smart systems integration and connectivity have to play an important role in this domain, with functional safety, fail-operational capabilities and user comfort being of primary concerns.

Second, it is obvious that the economically viable large-scale rollout of driving automation requires agreements on framework conditions between a large and heterogeneous group of stakeholders encompassing the automotive, IT, and telecom sectors as well as road infrastructure providers, public authorities and users.

To this end, two EU-funded Coordination and Support Actions "Safe and Connected Automation of Road Transport (SCOUT)" and "Coordination of Automated Road Transport Deployment for Europe (CARTRE)" are supporting the involvement of different stakeholders and will develop cross-sectorial roadmaps regarding the implementation of high-degree connected and automated driving in Europe. These may serve as blueprints for research and innovation funding and regulatory actions as well as support European Technology Platforms and a wide range of activities regarding connected and automated driving.

The International Forum on Advanced Microsystems for Automotive Applications (AMAA) has been exploring the technological foundations of new paradigms for many years. Consequently, the topic of the twenty-first edition of AMAA, held in Berlin on September 25 and 26, 2017 was "Smart Systems Transforming the Automobile". The AMAA organizers, VDI/VDE Innovation + Technik GmbH together with the European Technology Platform on Smart Systems Integration (EPoSS), greatly acknowledge the support given for this conference.

The papers in this book, a volume of the Lecture Notes in Mobility book series by Springer, were written by leading engineers and researchers who have attended the AMAA 2017 conference to report their recent progress in research and innovation. The paper proposals were peer-reviewed by the members of the AMAA Steering Committee. As the organizers and the chairman of the AMAA 2017, we would like to express our great appreciation to all the authors for their high-quality contributions to the conference and also to this book. We would also like to gratefully acknowledge the tremendous support we have received from our colleagues at VDI/VDE-IT.

Berlin, Germany
July 2017

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Part I
Smart Sensors

Smart Sensor Technology as the Foundation of the IoT: Optical Microsystems Enable Interactive Laser Projection

Stefan Finkbeiner

Abstract Consumer electronics such as smartphones, tablets, and wearables are part of our everyday life—visible everywhere and taken for granted. Less visible however are the small MEMS (micro-electromechanical systems) sensors that are an integral part of these devices. Smart sensor technology enables things to be sensed and connected—in all parts of our daily life, in homes, vehicles, cities. With the emergence of the Internet of Things (IoT), more and more devices become connected which results in demanding challenges for MEMS sensor technology providers—in addition to the trends of low cost, small size, low power consumption as well as overall system performance. The exciting developments in the IoT are advancing at an amazing pace. It is not just about how devices communicate or sense their surrounding environments, but increasingly about how technology interacts with human beings. Laser-projected virtual interfaces based on optical MEMS are a new fascinating solution in a world of previously unimaginable opportunities. They give any kind of device a unique personality of its own, enabling technology to interact with people, to make life simpler and more exciting. It is a ground-breaking solution for embedded projectors and augmented reality applications such as games, infotainment as well as in-car head-up displays or intelligent head lamps for automated driving.

Keywords MEMS · Sensor · Internet of things · IoT · Projector · Interactive · Head-up displays · HUD · Wearables

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1 MEMS Sensors—The Hidden Champions

MEMS (micro electromechanical systems) sensors are a key technology for the mobile and connected world. These compact electronic sensors are the hidden champions of everyday life, providing rich data used in a huge variety of applications, such as motion tracking, temperature sensing, and many others.

1.1 Enablers for the Internet of Things

Smart sensor technology enables things to be sensed and connected—in all parts of our daily life, in homes, vehicles, cities. With the emergence of the Internet of Things (IoT), more and more devices become connected which results in demanding challenges for MEMS sensor technology providers—in addition to the trends of low cost, small size, low power consumption as well as overall system performance.

To give just a few examples of where MEMS sensors are finding uses with the IoT:

- Parking spot detection
- Indoor and outdoor navigation
- Indoor air quality
- Sleep monitoring
- Intrusion detection
- Asset tracking
- Augmented reality
- Step counting
- Calorie tracking

In the IoT, everything will be connected. Today about 6 billion devices are connected worldwide, according market experts (source: Gartner). By 2020, this figure will have grown to 21 billion, with the global market for IoT solutions expected to be worth US $250 bn.

1.2 Challenges and Barriers for IoT Sensors

The IoT is technologically demanding for sensors. While there are many technologies available, they are not always adapted for IoT applications. In particular, power consumption must be low for always-on applications, and sensors must meet tough demands on size, scalability and cost.

There is also need for a high degree of customization, across a huge range of different applications in the home, vehicle, and city, and across many different industries. There is a lack of synergies and standardization across applications.

This means that vendors need deep application know-how, and the ability to meet the needs of low-volume customers.

The IoT is complex, which means cooperation and collaboration is needed between vendors. The value is in end-to-end solutions, so by establishing an ecosystem, companies can work together to cut time to market and deliver the right solutions.

1.3 The Role of Smart Sensors in the IoT

Smart sensor technology is the foundation of the IoT.

Highly integrated smart sensor hubs can handle the requirements of multiple, complex environments, and simplify the application design process.

Smart sensor hubs can overcome three key challenges:

- Technology: leveraging core MEMS and system know-how, to provide embedded intelligence in compact, high-performing devices, with low power consumption.
- Fragmentation: leveraging application knowledge, to provide an integrated solution including hardware and software, and in particular application-specific software
- Complexity: providing simple, turnkey solutions, and co-operating with third parties to deliver reference designs

For example, Bosch Sensortec's integrated sensor hubs BHI160 and BHA250 combine our lowest power sensors, best-in-class sensor data fusion software and an optimized microcontroller, to provide the lowest power solution without compromising features or performance.

2 Interactive Laser Projection

The IoT user interface is playing an increasingly important role in determining the type and amount of user input and the type and form of feedback received from technology.

We are essentially viewing the world through one screen or another. With our heads tilted down, we often live our lives inside of our smart devices, where smartphones eat up our time and, in a way, present an irresistibly addictive immersive environment for our information hungry senses.

Of course, there are many situations where a smartphone provides a very powerful user interface (UI) for accessing the active processes within our small part of the IoT universe. Nevertheless, we foresee many scenarios where the user interface will become indiscernible from the real and tangible world around us, appearing on demand within the context of where it is intuitively expected, but remaining hidden from sight when not required.

What a refreshing innovation it would be if our devices could project information straight out of the digital space on to the real world, thereby expanding the scope of our interaction with the IoT domain! This is now termed as "Mixed Reality".

The world is awash with sensors, devices and IoT applications, but it is our contention that the way that we interact with technology is currently undergoing a silent revolution.

In the upcoming decade, we foresee interactive laser projection fundamentally transforming our present concept of the user interface, of the way we technologically interact with our world. The exciting news is that interactive projection is here and now, no longer just on the movie screen—with the BML050 laser projection microscanner from Bosch Sensortec it has now become reality (Fig. 1).

2.1 Making User Interfaces Simpler, More Flexible … and More Fun

Let us take for example, a standard consumer appliance like an espresso machine. A high-end machine may have so many functions and features that the user manual

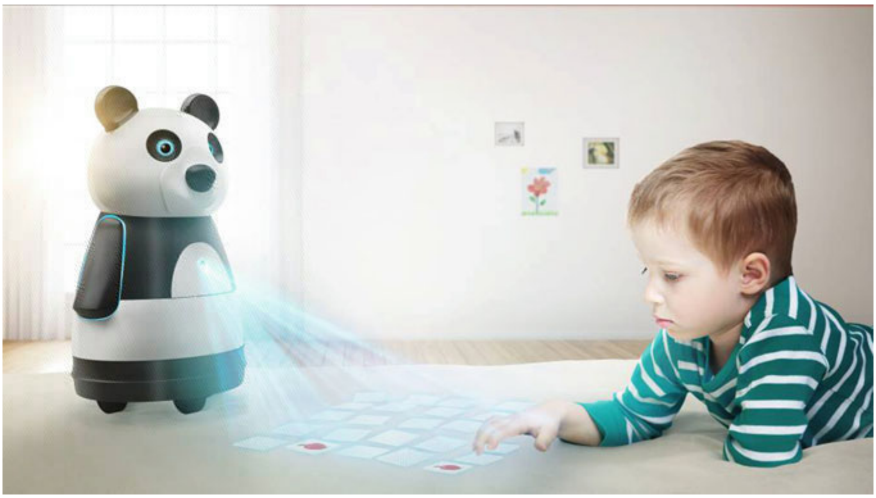

Fig. 1 Interactive projection with microscanner

is more complicated to navigate than Shanghai in rush hour—buttons, pop-up or drop-down menus, sliders, dials, knobs, lights, buzzers, radio tuner, etc., are we not just making coffee? And so, overwhelmed by complexity, the user leaves this modern monster gathering dust on the countertop and makes instant coffee!

With interactive projection, physical input/output elements are practically eliminated, thus fundamentally simplifying your espresso machine, toaster, or dishwasher. Making appliances and devices smaller and more intuitive, eliminating clutter and distractions will dramatically raise their appeal to the consumer. The projected user interface dynamically adapts and responds to specific user tasks, showing only relevant task-specific information. This means that complex, variable content is presented intuitively in a clean and easy-to-understand format. The coffee machine can now project a large, legible image on to any surface like a kitchen countertop or table.

The user needs only tap the projected button or menu item to set their preferred coffee specs. What is more, the user's interaction with technology is accompanied by the intuitive assistance of the system itself, making daily tasks more fun and hassle-free.

The display now functions even when the surface is obstructed or dirty, for instance when cooking. No more greasy fingerprints on your fine polished appliances—there is no need to physically touch them anymore, they will stay clean. In addition, the user can watch recipe videos on a virtual screen or chat with friends using a virtual keyboard.

2.2 Interactive Projection in Practice

To make all of this a reality, Bosch Sensortec has developed the BML050, a MEMS microscanner housing two MEMS mirrors, which when integrated into a complete projector reference design, project an RGB color laser image on to any kind of surface (Fig. 2).

Beyond laser projection, the BML050 also features the essential gesture sensing function. By measuring the optical feedback from illuminated objects, the system detects any interference between the user and the projected content. Since the optical feedback is determined by the position of the scanner, no calibration between projector and detection is needed. Just switch it on and press a button.

2.3 A Window to the IoT

Mixed Reality based on interactive projection will be utilized in all manner of devices, limited only by the design engineer's imagination.

Fig. 2 BML050 microscanner reference design

Furthermore, a complex UI environment consisting of dozens of individual screens and buttons poses a definite barrier to broader IoT adoption. Consumers simply cannot handle many more screens and buttons installed around their homes. Interactive projection provides a way to create on-demand interfaces, providing larger, clearer, more intuitive control elements that are hidden from sight when not required. The envisioned result is that homes will not be cluttered with any more screens and control panels—a clean wall approach—a connected world without any light switches, buttons or LCD displays.

Devices such as cooking appliances or service robots will be characterized by simple, clean design concepts. Usability will be much improved and manufacturers will be free to add many more value-adding features to their products without being limited by the physical interface.

For consumers, a context-related, menu guided UI will bring significant benefits. They can throw out their printed user manuals as intuitive help will always be on hand to guide them through the user interface, including video and images where required. Providing visual explanations makes devices substantially easier to use, particularly for people with an aversion to reading user manuals but in particular for elderly people or children facing the problem of how to get started with their new service robots. Interactive projection will complement the voice-controlled user interfaces that are currently penetrating the consumer electronics market.

Moreover, the projected image will not be limited only to the user interface function. It will be used to play videos and project graphics and texts, for example: recipes and YouTube cooking videos. It will also provide a way to access social media or make video calls to neighbors and friends.

2.4 *Interactive Projection for the Automotive Industry*

In the automotive industry, there are also many potential applications for interactive projection, with low cost integrated modules.

Head-up displays (HUD) and driver information can benefit from interaction, and other devices in the car can use projection for the human–machine interface, both for the driver and for passengers. Projected display can be accommodated also on curved surfaces, so that new design freedoms are opened up.

While HUDs today largely are reserved to the premium segment, it will be possible in the future to offer such systems even in compact and subcompact models with limited space and cost constraints, thus making an important contribution to improving road safety.

Interactive projection will also find uses in the more technical side of the industry, such as in car manufacture and repair.

2.4.1 Industry Teamwork

Leading manufacturers of light sources and micro-mechanical components, as well as a carmaker and an automotive supplier, have teamed up with a research organization to create the basics for highly integrated, economically producible laser projection modules for use in volume markets.

The research project PICOLO uses the results obtained within the framework of the Federation of MOLAS, in particular relating to green and blue laser diodes, as well as to the use of a MEMS scanner for the laser projection.

Very low cost is critical to achieve high market penetration, as well as highly integrated full-color-laser-projectors with power-saving driver electronics that can be manufactured in volume-capable production processes.

To achieve this goal, the development of high-efficient direct-green laser diodes is within the joint research project PICOLO, as well as developing suitable MEMS scanner and driver electronics, specific laser drivers, and high volume production capable, innovative concepts for integration.

Building upon initial works, Robert Bosch GmbH and BMW Forschung und Technik GmbH were involved. These partners will investigate the use of laser projection in low cost, building space reduced HUD modules, to the auto-stereoscopic 3D projection for the contact-analog display of information for driver assistance systems.

2.5 *Wearables and Beyond*

Interactive projection will also find many niches in wearables and other portable devices. It will play a key role in resolving the present dilemma of users wanting tiny, lightweight devices, while requiring large screens for managing increasingly sophisticated apps. The BML050 microscanner is compact enough for installation in portable smart devices.

The microscanner will most probably be heavily utilized in gaming to integrate mixed reality with projected images on real objects. Of course, navigation applications are a natural match, where the phrase of ‘knowing an area like the back of your hand’ will take on a new, much more literal meaning.

As this technology develops further, new applications that are still beyond what we can imagine today will emerge and soon become a natural part of our everyday lives. Perhaps 3 years from now, we might see smart glasses with a tiny interactive MEMS projector integrated in the frame. The wearer will see an image projected on to the lens providing information or augmented reality.

2.6 A Compact Module

While the concepts described above are still on the drawing board, the MEMS mirror technology enabling them is not. In 2017, the BML050 has been provided to selected customers, and will most likely go mainstream in 2018.

The BML050 microscanner is small and very power efficient, making it suitable for mobile and battery-powered devices. It delivers outstanding projection quality with advanced speckle reduction and precise control of the MEMS mirrors and laser

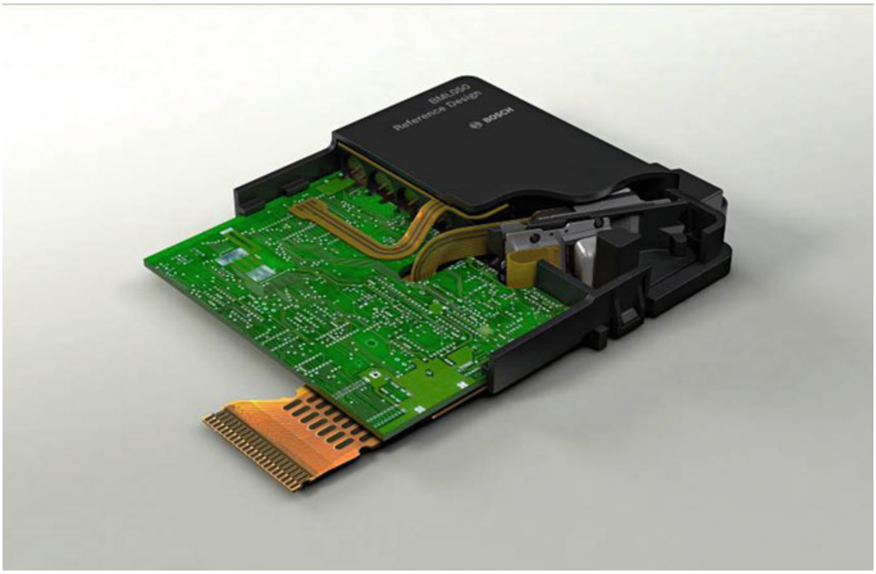

Fig. 3 BML050 microscanner reference design

diodes. Projection is focus-free, and its vivid laser colors exceed the natural color spectrum perceptible to the human eye.

A reference design will be available for evaluation by the second half of 2017. This microscanner is a fully aligned, ready-to-go calibrated solution, which includes all the MEMS mirrors and control circuits, lasers and laser drivers, and power management in a single compact package (Fig. 3).

3 Conclusion

With the Bosch Sensortec BML050 MEMS scanner, engineers will transform how we create brand new user interfaces in many products. Interactive projection will make daily life much easier and more exciting for consumers and will remove many of the present barriers to IoT adoption, including many automotive applications.

At this stage, the technology is ready for mainstream implementation, and we are looking forward to seeing where designers will take it. We foresee an exciting period of innovation ahead.

Unit for Investigation of the Working Environment for Electronics in Harsh Environments, ESU

Hans Grönqvist, Per-Erik Tegehall, Oscar Lidström, Heike Wünscher, Arndt Steinke, Hans Richert and Peter Lagerkvist

Abstract When electronic equipment is used in harsh environments with long expected lifetime, there is a need to understand that environment more in detail. This situation is today a reality for many application areas including the automotive sector, heavy industry, the defense sector, and more. To fully understand the working environment, a unit has been developed to monitor physical data such as temperature, vibration, humidity, condensation, etc., to be used in the product development phase for new products. This paper presents the underlying principles for the ESU (Environmental Supervision Unit) and details on the design.

Keywords Harsh environment · Monitoring unit · HALT · Condensation sensor · Multi sensor unit · Reliability

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1 Introduction

The basic idea behind the project is to provide the industry with a unit for monitoring the environment for the customers' electronics units during the development phase and/or during actual use. This ESU (Environmental Supervision Unit) can be configured in many different ways using transducers for different physical parameters. The rationale for this is that in order to design electronics equipment that needs to be reliable in harsh environment, there is a need to understand this environment in detail.

Reliability of an electronic product is normally assured by designing, manufacturing, and testing them according to standards. These standards are based on best practice of mature technologies and the main focus is to assure good manufacturing quality. However, new types of components such as QFN and fine-pitch BGA components may have inadequate solder joint life even if they have been produced with perfect manufacturing quality. This is mainly a problem for high reliability products that are expected to have a long life in harsh conditions. The main factors affecting the life of solder joints are thermomechanical stress due to temperature variations and mechanical stress due to vibration or shock. Therefore, in order to assess the life of solder joints it is necessary to have information of the stresses solder joints will be exposed to during the whole life of the product, not only during service but also during handling and storage. It is not only the maximum and minimum temperatures and the maximum vibration levels that need to be determined. The number of temperature cycles with different delta temperature and the variation in vibration levels must be known in order to facilitate assessment of the life of the solder joints.

In addition, condensation of water on the board of electronic equipments is a well-known cause of failures.

In an ongoing Swedish national project, "Requirements specification and verification of environmental protection and life of solder joints to components", the ESU will be used for characterizing the actual field environment for a number of products used in harsh environments. This will give information of the usefulness of the ESU. The project is supported by the Swedish Governmental Agency for Innovation Systems (VINNOVA).

2 Monitoring Unit, ESU

The SME Setek Elektronik AB located in Gothenburg, Sweden, is currently investigating the market potential for the ESU and will build a number of prototypes to be evaluated by an industrial reference group. This group consists of vehicle manufacturers, (cars, trucks, trains, boats, etc.) in the project "Requirements specification and verification of environmental protection and life of solder joints to components" mentioned earlier.

The transducers for the current version of the ESU is equipped with

- Condensation sensor provided by CiS. (A unique sensor on the market)
- Several sensors for temperature. (Commercial)
- Sensor for relative humidity. (Commercial)
- Sensor for vibration, acceleration, and displacement. (Commercial)
- A large memory for storing environmental data for long times

Figure 1 shows the current design and Fig. 2 shows that particular sensor. A more detailed layout of the sensor chip is shown in Fig. 3.

The basic functionality of the condensation sensor is: Condensation leads to the formation of droplet of the sensor surface. The detection of droplet bases on the capacitive principle using an electric stray field on a dense surface. The principle is shown in Fig. 4. The packaging withstands the corrosive properties of condensate over many years. The upper passivation layer consists of silicon nitride, is mechanical stable, and allows a cleaning if necessary. It enables the detection of droplets as small as some µm on the sensor surface. The overall impedance of the stray field capacity shows a marked frequency response, which is greatly dependent

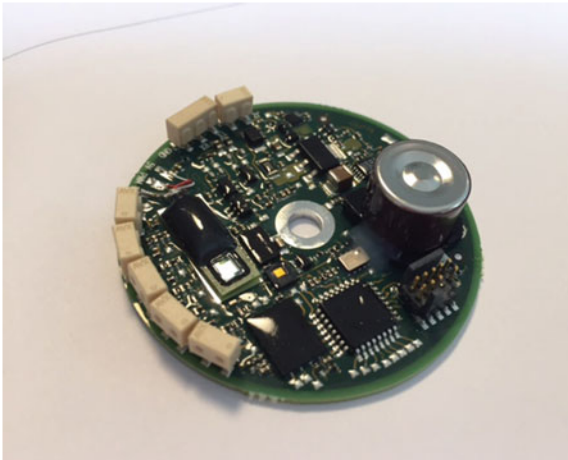

Fig. 1 Picture of the prototype

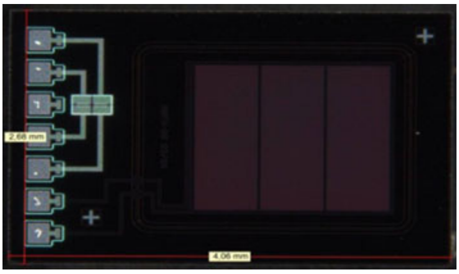

Fig. 2 Picture of the unique condensation sensor