Semiconductor enabling a connected and automated car

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MathWorks, Stuttgart
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4 megatrends are shaping Automotive market significantly increase of semiconductor content of vehicles

<table>
<thead>
<tr>
<th><strong>ADAS/Autonomous driving</strong></th>
<th><strong>xEV/eMobility</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>› From ADAS to semi-automated and finally autonomous driving</td>
<td>› Mandated CO₂ reductions make electrification of powertrain inevitable</td>
</tr>
<tr>
<td>› Every world region is striving for &quot;0-accident&quot;</td>
<td>› Advanced connectivity is driven by making the car part of the Internet</td>
</tr>
<tr>
<td>› Increased connectivity and software content increase risk exposure to hackers</td>
<td>› The car will be fully connected (V2I, V2V, in-vehicle)</td>
</tr>
<tr>
<td>› Internal/external connectivity must be secured</td>
<td></td>
</tr>
</tbody>
</table>

**Advanced security**

**Connectivity**
Building blocks of automated driving: Cooperation of multiple system and disciplines is key

Data processing and decision making

Sensing

Vehicle dynamics and control

Software
- Decision Making
- HMI

Fusion
- Sensor Data
- Central Computing

Connectivity
- DSRC, Wi-Fi
- Cellular

Vehicle Sensors
- Radar,
- Ultrasonic,
- Camera, Laser,
- GPS, Maps

Suspension

Transmission

Braking

Engine

Vehicle Sensors

Sensing

Data processing and decision making

Software
- Decision Making
- HMI

Fusion
- Sensor Data
- Central Computing

Connectivity
- DSRC, Wi-Fi
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Transmission

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Engine

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Driver's senses will be replaced by a cocoon of sensors in various technologies

The safety cocoon through sensors
Any next automation level requires more sensors and thus higher level integration → Higher level of simulation/training

<table>
<thead>
<tr>
<th>Application*</th>
<th>Level of automation</th>
<th>Radar # of modules**</th>
<th>Camera # of modules**</th>
<th>Lidar # of modules**</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 2</td>
<td>≥ 3</td>
<td>≥ 1</td>
<td>0</td>
<td>Ultrasonic</td>
</tr>
<tr>
<td></td>
<td>Level 3</td>
<td>≥ 6</td>
<td>≥ 2</td>
<td>≤ 1</td>
<td>Ultrasonic Interior camera</td>
</tr>
<tr>
<td></td>
<td>Level 4/5</td>
<td>≥ 10</td>
<td>≥ 8</td>
<td>≥ 1</td>
<td>Ultrasonic Interior camera V2X***</td>
</tr>
</tbody>
</table>

* Source: VDA (German Association of the Automotive Industry), Society of Automotive Engineers  
** Market assumption; *** See glossary
360° Radar requires a new type of sensor, bus- and processing-architecture

**More radars** in the car in area with less space and worse thermal condition

→ **Small sensors**
→ **Low power consumption**

**Sensor fusion** needed to get best performance in dense urban situation

→ More (raw) data from sensors required in central fusion box → **higher data rates**

**More sensors** in the car lead to higher wiring effort

→ **Cost efficient architecture** and **inexpensive wiring** (un-shielded twisted pair)

Small-form-factor of multiple near-range radar-sensors are the important enablers for autonomous cars
Complextiy is increasing and new methodologies are needed. Simulate and drive in the computer is the only chance.

Current Utilization Simulink/Matlab:
- Functional Modelling for HW accelerator IP development
- Model C-code generation -> built as MEX
- Reference for verification + validation
- Radar system simulation (Matlab & MEX) built as Embedded SW

Enhancements expected in the future:
- Radars with more modulations (PMCW, OFDM etc.) besides FMCW
- 64-bit integers
- Fixed-point toolbox is very slow
- FUSI: Matlab generates different code under Simulink and Embedded HW. FUSI requires
- Parallel execution of system simulation regression, test-cases in different computing unit (GPU, FPGA etc.)
- Scenario Generation
- Ray tracing
- Different target models for complex targets (e.g. set of point targets for car/pedestrian/infrastructure objects)
- Sensor Fusion: multiple sensors on ego-vehicle as well as on multiple vehicles in the environment
Sensor network and V2X data volumes require more computing performance and new domain architecture.

**New technologies/sensors**
- Lidar, sensor networks
- High-resolution maps
- Car-to-X connectivity

**New computing architecture**
- GPU architecture
- New SW architecture, e.g. Hypervisor
- Integrated security architecture

**New business models**
- SOTA updates and new applications
- Big data
- New insurance models
Introduction of central computers triggers demand for high-performance, fail operational microcontrollers (MCUs)

**L0 / L1 / L2 vehicles**
- **basic car functions**
  - temperature
  - pressure
  - position
  - speed
  - MCUs, e.g. AURIX™

**human acts**

**future ECU = classic ECU**
- + higher performance
- + fail operational
- + secure

**fail operational systems require redundancy in**
- power switches, power supply
- sensors
- MCUs

**car security is achieved through**
- discrete security controller (OPTIGA™)
- integrated security modules in MCUs (AURIX™)

**L3 / L4 / L5 vehicles**
- **central computer triggers car operations**
  - camera
  - radar
  - lidar
  - GPS
  - MCU (AURIX™)

**central computer**
- CPU / GPU
- + MCU (AURIX™)
From ECU to domain architecture: Secure μC from Infineon offer the required safety and necessary scalability

Sensor fusion

AURIX™ as main or host controller

Radar & camera

AURIX™ as main* or host controller

Domain control

AURIX™ as hard-realtime main processor

Connectivity gateway

AURIX™ as hard-real time main controller

Always-on connectivity

AURIX™ as host controller

*for radar
AURIX™ microcontroller complements CPU/GPU to make the central computer robust and fail operational

Examples of central computing platforms

<table>
<thead>
<tr>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>› Data processing for applications (e.g. parking)</td>
</tr>
<tr>
<td>› Fusion of object data, deep learning algorithms</td>
</tr>
<tr>
<td>› Environmental model calculation (road, objects)</td>
</tr>
<tr>
<td>› Trajectory planning</td>
</tr>
<tr>
<td>› Modelling of driver behaviour</td>
</tr>
</tbody>
</table>

AURIX™ as real-time main controller or host controller

› ISO 26262 ASIL-D safety host monitoring operation of the data fusion ECU
› Safe and secure gateway to the vehicle network
› Fallback operation in case of a GPU/CPU fail
› Safe communication to actuator control units

Cooperation is needed to combine automotive world with high performance computing

Pictures: Courtesy of Nvidia, Intel
Infineon addresses a wide range of xEV components – from Main Inverter to Auxiliaries

### Key Components of Electric Vehicles

- **DC-DC**
- **DC-AC**
- **Onboard charger**
- **Main Inverter**
- **PTC heating**
- **Water pump**
- **Cooling compressors**
- **Oil pump**

### Categorization of Key Components

<table>
<thead>
<tr>
<th>Category</th>
<th>Component</th>
<th>Power [kW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Inverter</td>
<td>Main Inverter</td>
<td>30 – 400</td>
</tr>
<tr>
<td>Power Supply</td>
<td>OBC</td>
<td>1.5 – 6.6</td>
</tr>
<tr>
<td>Power Supply</td>
<td>DC-DC</td>
<td>1.5 – 2.5</td>
</tr>
<tr>
<td>Heater</td>
<td>PTC Heater</td>
<td>2 – 5</td>
</tr>
<tr>
<td>Motor Drives</td>
<td>Compressor</td>
<td>1.5 – 5</td>
</tr>
<tr>
<td>Motor Drives</td>
<td>Water Pump</td>
<td>0.2 – 1</td>
</tr>
<tr>
<td>Motor Drives</td>
<td>Oil Pump</td>
<td>0.2 – 1</td>
</tr>
</tbody>
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OBC = On-Board-Charger

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A comprehensive product portfolio requires an advanced simulations & design environment for xEV applications.

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- Generation of code as Embedded SW

Use Case today and in the future:
- Optimization of power converters (specially SMPS) simulation
- Simulation deployment on FPGA based platforms (including Speedgoat and dSpace)
- First proof of concept done with MathWorks’ AE support (improvement of factor x3)
- Closed loop simulation for verification control algorithm and power electronics
- First proof on concept with translation of Spice models to MathWorks
- Multi-domain simulation and Analog-Mixed signal simulations
- Hydraulic/Mechanical/Electrical block modeling (e.g. transmissions)
- IDE with workflow that supports FS (ISO26262)
- Automated code generation for uC and Control algorithm analysis

Expectation and Improvements which helps in NEW designs:
- Real-time (or near to real-time) simulation speed
- HDL coder support for physical modeling tools
- Interface between IFXspice (Titan) and MathWorks toolboxes
- Tool for FS analysis (like Medini form ANSYS)
- Multi-core support
The connected car offers many use cases for our customer. Move from closed to open system introduces multiple risks.
Security is not just one more feature in the modern car
Safety and Security are intrinsically linked

- Danger of unintentional errors disrupting the safe operation of the vehicle

Intentional attacks on systems and software

“It must not happen”

“It must not pay off”

A safety or security breach could result in the same consequence: **Threat to life and limb**
A single firewall will not be enough! Various security tools have to be added on the way to a secure architecture.
A single firewall will not be enough! Various security tools have to be added on the way to a secure architecture

- Dynamics control
- Energy management
- Transmission

ADAS domain:
- Radar
- Camera
- Lidar

Body & comfort domain:
- HVAC
- Lighting
- Immobilizer

Driving domain:
- ... (other components)

Infotainment domain:
- Head unit
- E-Call
- Connectivity

Trust anchors:
- Protected execution environments hosting
  - Key storage and related cryptographic operation
  - Security applications

Integrated on MCU:
- High speed
- Secure onboard communication
- Logical security

Discrete security controller:
- External communication
- Protecting high value
- By certified hardware security

Enabling the root of trust for internal and external communication
Semiconductors enable the future of driving: More safety, more comfort, less pollution

› Semiconductors enable ~80% of innovation in automotive
› Autonomous driving will increase safety and comfort, but also support CO₂ reduction
› A secure system architecture combined with hardware security will provide the appropriate level of protection
› SIMULATION is key to shorten time to market and reliable system
Part of your life. Part of tomorrow.

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