Component Selection
The Make-or-Break Milestone Towards Autonomous Vehicles

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J U N E . 2 0 1 5
Agenda

- The Evolution of the Automotive Electronics Market
- Industry Risk — Consumer Components in Safe Automotive Applications – ZVEI* Work Group
- Truly different: Automotive Semiconductors and Consumer Components! – Fact Sheet
- Freescale Value Creation Towards Autonomous Driving — Examples
- “Autonomous Driving Crossroad”

*ZVEI: German Industry Association of Electric and Electronic Industry
Growing Number of Automotive Electronics Applications

“80% percent of innovation is electronic”
“Impossible to comply with regulation without electronic systems”
-Automotive OEM

Electronic cost as % of total car cost

- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2005
- 2010
- 2025?

Advanced Driver Assistance
Radar / Vision
Green Powertrain
Telematics
Infotainment/Graphics
Connected Vehicles

Autonomous Vehicles

E.g. Audi A8: 100 ECUs, 270MB of S/W

Growing Number of Automotive Electronics Applications

- Electronic Fuel Injection
- Airbag
- ABS / ESP
- Body Electronics
- Multiplexing
- Advanced Driver Assistance
- Radar / Vision
- Green Powertrain
- Telematics
- Infotainment/Graphics
- Connected Vehicles

“80% percent of innovation is electronic”
“Impossible to comply with regulation without electronic systems”
-Automotive OEM

E.g. Audi A8: 100 ECUs, 270MB of S/W
Automotive Moving Towards Leading Edge Technology

Advanced Driver Assistance System Applications

- The next generation of automated driving requires leading edge compute intelligence to exchange and evaluate all the data.
- This level of compute power may not reside in a controller specifically designed for automotive.
Exploding R&D Costs in the Semiconductor Industry
(extract Baden-Baden 2012)

- R&D increases caused by
  - Growing technology complexity
  - Growing product complexity
  - Growing materials cost: wafers and masks
  - Enablement, software, solutions creation

<table>
<thead>
<tr>
<th>R&amp;D spending as % of sales in the semiconductor industry</th>
</tr>
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<tbody>
<tr>
<td>Late 70’s, early 80’s</td>
</tr>
<tr>
<td>Early 90’s</td>
</tr>
<tr>
<td>2000–2010</td>
</tr>
<tr>
<td>2008 record</td>
</tr>
<tr>
<td>2011</td>
</tr>
<tr>
<td>2012 Forecast</td>
</tr>
</tbody>
</table>

Source: McKinsey 2011

McKinsey Oct. 2013:
“Complex integrated chip designs now exceed $100M, with designs of $20M – $30M becoming commonplace among more standard or basic components. Consider a $100M development investment. It’s business case typically demands at least a $500M return.”

\[
\text{Nbr of NPI} = \frac{\text{Market Size} \times (\% \text{ corp. R&D} \times \% \text{ product R&D})}{\text{R&D$ per NPI}} \times \text{Technology Cycle Time}
\]

Source: VLSI Research Dan Hutcheson (modified)

<table>
<thead>
<tr>
<th>32-bit Auto MCU example</th>
<th>values</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market size 32-bit Auto MCU</td>
<td>$3,336 M</td>
<td>Units x ASP 2011 data from Strategy Analytics</td>
</tr>
<tr>
<td>Avg. corporate R&amp;D</td>
<td>15%</td>
<td>2011: 15.5% industry average</td>
</tr>
<tr>
<td>Avg. Product R&amp;D *</td>
<td>50%</td>
<td>Amount of corporate R&amp;D$ dedicated to product development</td>
</tr>
<tr>
<td>Avg. R&amp;D$ per NPI **</td>
<td>$10.0 M</td>
<td>Exploding R&amp;D costs (cost point for 55 nm; &gt;50% increase per technology node)</td>
</tr>
<tr>
<td>Technology cycle time</td>
<td>3 years</td>
<td>New technology node every 3 years</td>
</tr>
<tr>
<td>Max number of NPI the industry can afford in one technology cycle</td>
<td>75 in 55 nm for the total auto industry! across all applications, across all suppliers</td>
<td>50 in 40 nm 33 in 28 nm</td>
</tr>
</tbody>
</table>

* Source VLSI research
** Source: Freescale estimate
The Future of Components Used in Automotive

• Automotive represents only 10% of the global semiconductor market*
• The variety of products requested continues to rise
  – Growing number of applications
• R&D investment required for leading-edge components is exploding
  – Automotive requirements add substantial costs
• The number of products that the automotive market can justify will reduce substantially
  – Specifically affecting the high-performance space
• The automotive players need to find ways to also integrate “standard components”** into vehicles while meeting quality, reliability, lifetime and safety targets

* Source: WSTS 2014
** Any components not specifically developed for target market automotive
Industry Risk — Consumer Components in Safe Automotive Applications – ZVEI Work Group
Problem Statement - Example

- Memory stacked-die BGA module construction designed for consumer use case
- Fit for use in mobile phones, but bond wire cracks will create reliability issues in Automotive use case
- Differences in mission profile e.g. vibration, temperature cycles
  - Various Auto mission profiles possible in the vehicle
- This is not „poor quality“
  - Systemic designed-in capability
  - Successful design for target mission profile
  - Product reliability frozen after product design
  - No compensation by „try harder“ in production

Sources:
2.) IFAS GmbH, Dortmund, Germany
The targets of the new ZVEI* work group (founded Jan ‘14)

1. Create awareness: all potential differences — automotive vs. consumer components

2. Define a collaboration process with car OEM / Tier1 on vehicle / ECU development to:
   - Identify potential risks
   - Conscious decisions on how to resolve or mitigate applicable risks
     - Closed-loop communication
     - Resulting in robust system level solutions
   - Align change management & product life cycle/availability expectations with typical standard component cycles
   - Accept/refuse the consequences of remaining shortcomings incl. risks for incidents and field failures

*ZVEI: German Industry Association of Electric and Electronic Industry
Consumer Components in Safe Automotive Applications
What Happened So Far, Who is Engaged?

• Participating companies:  (add. members joined since Oct ´14*)

*Atmel, Fairchild, Harman, Leopold Kostal, Murata, Osram, Taiyo Yuden, Texas Instruments, Vishay, as well as Mr. Keller and Mr. Gresch

• First brainstorming Dec 2013 in Munich
• Work group kick-off January ´14
• Work group leader: Stephan Lehmann / Freescale
  - July ´14: Final release of position paper
  - Sept ´14 — involve Tier1 members of ZVEI
    ▪ Bosch, Hella, Marquardt, Brose, TRW, Kostal, Webasto, Harman, Siemens
  - Work Group support expanding since Q4/14:
    ▪ Atmel, Fairchild, Harman, Kostal, Murata, TI, Osram, (Intel)
  - Feb 11th: Fact Sheet release “Pot. differences between automotive targeted components and consumer components”
  - Next step: approaching CarOEMs
  - While this initiative started in Europe, it is relevant to all of us globally and Freescale invites you to connect!
Position Paper Available — English and German

Topical summary in brief:

- Increasing demand to use consumer grade semiconductors in vehicles
- Truly different: automotive semiconductors and consumer parts
- Resulting new and growing industry risks often unknown
- Automated driving vision requires new level of industry-wide cooperation
- Experienced automotive suppliers in ZVEI reach out to OEMs

Downloads via ZVEI-Homepage:

Truly Different: Automotive Semiconductors and Consumer Components! – Fact Sheet
Truly Different: Automotive Semiconductors and Consumer Components

- 6 categories for potential differences:
  - Technology Development — Semiconductor
  - Technology Development — Packaging
  - Component Development — Product Design
  - Component Validation, Characterization, Qualification
  - Component Manufacturing, Production, Test
  - Component Supplier — Applicable Standards and Processes / Added value support

- 66 possible differences have already been identified by the ZVEI work group. Components and suppliers satisfy criteria to varying degree.

Component capability is frozen latest at the end of product design

* DFT: Design for Test, DFM: Design for Manufacturability
** FA: Failure analysis, FQE: Field Quality Engineering
Fact Sheet Content

- Fact Sheet finalized in February 2015
- Most comprehensive list of potential differences in the industry
- * Other identified relevant Industry publications:
  - VDA* - OEM consumer component risk assessment guideline
  - BMW Group Standard (rev 2013, new revision in preparation in collaboration with 2nd OEM)

Describing the two extremes, there are many “shades” between them – both in requirements and capabilities

VDA: Association of German Automotive OEM (members incl. OEM and Tier1)
# 66 Potential Differences — Automotive vs. Consumer

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Metal line Electro-migration caused by current density</th>
<th>TDDDB (Time dep. Dielectric breakdown) — Metalization</th>
<th>TDDDB — Transistor Gate oxide Lifetime</th>
<th>Transistor Aging margin for Auto lifetime degradation</th>
<th>Radiation Susceptibility (SER/SEL)</th>
<th>NVM Data Retention</th>
<th>NVM write/erase</th>
<th>NVM Programming</th>
<th>Technology Certification</th>
<th>Reliability Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction Chip/Package</td>
<td>Wire bond integrity (Gold, Cu, etc)</td>
<td>Alternative Package connection technology</td>
<td>Mold compound</td>
<td>BOM flexibility</td>
<td>Design Rules</td>
<td>Package types</td>
<td>Board level reliability</td>
<td>Product definition</td>
<td>Requirements management</td>
<td>R&amp;D partnership</td>
</tr>
<tr>
<td>R&amp;D project management</td>
<td>Robust Design</td>
<td>DFMEA</td>
<td>Design-for-test (DFT)</td>
<td>ECC</td>
<td>Design-for-manufacturability (DFM)</td>
<td>Design-for-(Failure)-Analysis (DFA)</td>
<td>Std Cell libraries</td>
<td>Power consumption</td>
<td>Latchup</td>
<td>Functional Safety Functions</td>
</tr>
<tr>
<td>APQP support</td>
<td>Qualification acc. to AECQ100</td>
<td>Drift Analysis</td>
<td>Characterization</td>
<td>PPAP</td>
<td>Test insertions &amp; test coverage</td>
<td>Memory ECC testing</td>
<td>Zero defect test screen strategy</td>
<td>High voltage stress and/or burn-in</td>
<td>PFMEA</td>
<td>Process Controls</td>
</tr>
<tr>
<td>Manufacturing margin / Cpk</td>
<td>Sub-Supplier &amp; Subcontractor</td>
<td>Supply security</td>
<td>Quality Management system / cert. acc. TS16949</td>
<td>VDA audit support (VDA 6.3)</td>
<td>product maturity</td>
<td>FA &amp; 8D support</td>
<td>Commitment to confirmed ppm target</td>
<td>Traceability</td>
<td>Record retention</td>
<td>MAT Label</td>
</tr>
<tr>
<td>PCN handling</td>
<td>product life-cycle management</td>
<td>EOL handling &amp; stock</td>
<td>FMEA</td>
<td>Supply Agreements &amp; CSR</td>
<td>Automotive system design support</td>
<td>EMC - ECU design support &amp; component certification</td>
<td>ISO26262 related support</td>
<td>Automotive Software Development</td>
<td>pro-active quality alert process</td>
<td>Material compliance &amp; declaration</td>
</tr>
</tbody>
</table>

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External Use | 16 | #FTF2015
The “Bath Tub Curve” — Quality & Reliability in a Typical Automotive 125°C Mission Profile

- Right slope is frozen after technology, packaging & product development & can only be influenced by temperature profile

Typical consumer component

Less reliable technology

Limited DFM effort in design

Limited test coverage / DFT

Safe launch

8D corrective actions

Automotive component

ppm

100

10

1

Life time years

5 10 15 20

DFT – Design for Test

DFM — Design for manufacturability
Consequences of the Differences on Automotive Use

- Component selection risks do not only impact companies, but might lead to direct, personal consequences for the responsible employee or manager.
- Zero defect quality & 15 year+ reliability at ECU level in many cases cannot be accomplished with standard components ALONE.
- Shortcomings can be mitigated by collaboration between Car OEMs, Tier1 and component suppliers:
  - Modified vehicle and/or ECU mission profile
  - System level solutions e.g.
    - Redundancy
    - External component protection
    - Cooling
- Remaining risks need to be understood and accepted by all participants.
Development Partnership

• The component selection defines how long and risky the application development will be
  - **Product:** size of gap at sourcing decision
  - **Partner capabilities:** potential risk reduction slope
  - **Collaboration:** realized risk reduction
  - **Consequence:** final remaining risks
Freescale Value Creation
Towards Autonomous Driving — Examples
ZVEI Fact Sheet “Consumer Components in Safe Auto Applications” — What it Boils Down To

- Product originally designed for Automotive / new supplier
- Product not specifically developed for Auto / new supplier
- Product originally designed for Automotive / experienced Auto supplier
- Product not specifically developed for Auto / experienced Auto supplier

Freescale

Automotive Newcomer
# Product & Application Examples

- Freescale offering highly differentiated products and/or services based on conscious decision process & understanding of implications

<table>
<thead>
<tr>
<th>Application</th>
<th>Product</th>
<th>Freescale Strategy</th>
<th>Freescale offering</th>
<th>Unique differentiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wireless Charging</td>
<td>DSC (MCU + DSP integration)</td>
<td>1 — non-Auto with Freescale value</td>
<td>MWCT100xA</td>
<td>Lowest application EMC &amp; optimized Software</td>
</tr>
<tr>
<td>Autonomous Driving</td>
<td>High performance processor QorIQ</td>
<td>1 — non-Auto with Freescale value</td>
<td>(Layerscape) LS2085A T4240</td>
<td>Highest reliability even in most auto mission profiles, 10–15 years guaranteed longevity</td>
</tr>
<tr>
<td>Graphics / Cluster / Infotainment</td>
<td>Graphics processor</td>
<td>2 — non-Auto with partial Auto Design &amp; Freescale value</td>
<td>i.MX 6 families</td>
<td>Industry benchmark ppm due to DFM / DFT design flow</td>
</tr>
<tr>
<td>HV battery management</td>
<td>integrated 14-cell lithium-ion battery cell controller</td>
<td>3 — Full Automotive Design instead of non-Auto source</td>
<td>MC33771, MC33664</td>
<td>State-of-the-art: ASIL C safety concept, ISO26262 design flow, full Automotive reliability, Auto driven functionality &amp; higher integration</td>
</tr>
<tr>
<td>Vision ADAS*</td>
<td>Safe Vision processor</td>
<td>3 — Full Automotive Design instead of non-Auto source</td>
<td>S32V200 family</td>
<td>State-of-the-art: ASIL B/C safety concept, ISO26262 design flow, design for reliability and zero defect</td>
</tr>
</tbody>
</table>

* ADAS: Advanced Driver Assistance System
Progress Toward Autonomous Vehicle

Freescale Contribution

- **Self Driving**
  - Automated Driving (Blending the Objects)
  - Assisting the Driver (Efficient Sensor Streams to data object)
  - Passive to Active Safety (Automotive Chassis & Powertrain)

- **Massive Computing & Connectivity Management**
  - Open Distributed Computing & In vehicle connectivity
  - Integration with Safe Performance
  - Auto Reliability & Quality

- **Massive Computing**
  - Sensor Fusion Platforms (Map the territory)
  - Smart Sensor Platforms (Radar, Vision, MagniV)
  - Automotive Platforms (mC, Sensors and Analog and SW)

Automotive competence combined with reliable, safe and secure, SW enabled, massive performance
Computing Challenges — FSL Solution

Super Computing

Safe Computing

Automated Drive | Co-Pilot | Collision Avoidance | Self Parking | Lane Keeping | Collision Warning | Sign View

Probabilistic
1. Analyze Scenario
2. Make Contextual Decision

Deterministic
1. Initiate Safe Measure
2. Fail Safe / Operational

Number Cruncher
Layerscape
72,000 DMIPS

Safety Processor
S32 V200
10,000 DMIPS

—

$72,000 DMIPS

$10,000 DMIPS

—
Freescale Advanced Product Quality — Example S32V200

- AECQ100 qualification only tells how bad — not how good — a part is
- Freescale quality & reliability grown in 40 years of Automotive commitment
- Many of those capabilities fan-out to full Freescale product portfolio
Addressing the Challenges of Functional Safety
Freescale SafeAssure Program

• Designing safety-critical systems while meeting state-of-the-art functional safety requirements can be challenging

• **Freescale is a leading supplier of safety solutions**
  - More than 15 years of experience of designing products for safety related applications
  - Shipped more than 70 million MCUs and 60 million Analog products into safety systems such as electronic stability control and anti-lock braking

• Our **SafeAssure** program helps automotive and industrial OEMs **achieve end system compliance with functional safety standards**

• Certification of the SafeAssure hardware development process for analog and sensors as suitable for development of ISO 26262 compliant hardware product components underscores **our commitment to simplifying the process of achieving system compliance.**
Freescale Differentiated Value Creation Towards Autonomous Driving

- Conscious & data driven design-for-reliability & quality decisions
  - Across portfolio
  - Re-assess different mission profiles
  - Understanding implications of our decisions
- Extended technology certification — support application design margin
- Safe Assure Safety leadership — Product, Software, Documentation, Support
  - Certified R&D processes for safety products
  - Understanding implications of gaps
- Quality support e.g. FA / 8D
- Product longevity — 10 years (ind./networking) & 15 years (auto)
- Std. Processes across Freescale:
  - FMEA, DFMEA, PFMEA, subcon management, EOL, IMDS, excursion elimination, reliable NPI flow, TS16949

Auto foundation: Conscious fan-out across full product portfolio
Autonomous Driving - Crossroad

Autonomous Driving will change the Automotive world completely & creates substantial new hardware challenges that need attention by Tier1 and CarOEM. Component selection risks do not only impact companies, but might lead to direct, personal consequences for the responsible employee or manager.

- Freescale offers differentiated strategies across the complete required performance range
- Customer value comes from product, but even more from supplier capability
- Success factor: data driven risk identification & understanding implications based on conscious Freescale decisions
- Which partner do you trust helping you towards solutions that will autonomously drive your children?