Outline

• Automotive Electronics: Increasing Content Over Time

• Implications
  - *New functions*: new packages
  - *Higher density*: smaller packages & higher integration
  - *Higher density*: higher ambient temperatures
  - *More components*: lower cost & higher reliability
Automotive Electronics
Key Trends
Automotive Trend: Increasing Electronics Content

- The long-term trend in automotive electronics is increasing content over time.
- This trend is decades-long and expected to continue.

1929: 1st automotive electronics

![Image of early automotive electronics](image)

Source: Strategy Analytics (Mar’14)
Automotive Trend: Increasing Electronics Content

- The trend of rising electronics content in cars is expected to continue, both in dollar value and in number of components.
- This growth is broad, spanning multiple functions, and holds significant implications for the industry.

![](Average Electronics Content per Car, (Value).png)

![](Average Electronics Content per Car, (Components).png)

Source: Strategy Analytics (Jan’14)
What is Driving the Growth in Electronics Content?

- **Autonomous Driving**
  - Advanced Driver Assistance Systems (ADAS)

- **Clean & Green**
  - Reduced emissions vehicles

- **Connectivity & Entertainment**
Automotive Electronics
Packaging Implications

New Functions: New Packages
New Functions: New Packages

• There is an explosion of new electronics applications in cars.

• Many of the new functions drive unique packaging requirements.

• Examples:
  – Automotive radar systems
  – Hybrid power modules
Intelligent Cars & Traffic Management Systems
Fan-out packages are being adopted for mmWave applications.

Redistributed Chip Package (RCP)

- Dramatic **volumetric shrink** of current and future systems: **40-90%**.
- Increased functionality via **heterogeneous integration**.
- Improvement in **system performance** (low parasitics, low inductance).
- Improved **board level reliability**.
Reduced Emissions Vehicles

Cleaner world

- Increased fuel efficiency
- Smarter transmissions
- Alternate drive-trains
  - Mild hybrid
  - Full hybrid
  - Electric vehicle
Hybrid Power Modules

- Hybrid and Electric Vehicle (HEV) drive-train requires multiple unique components.

- Essential component for drive train is IGBT inverter module:
  - High current (800 A)
  - High voltage (650 V)
  - High power dissipation
  - Multiple IGBT & control chips

- Packaging solution:
  - Multi-chip module
  - Ceramic substrate
  - Water-cooled copper cold plate

- Similar problem, similar solution: IBM Thermal Conduction Module (TCM) ~ 1982
Automotive Electronics Packaging Implications

Higher Density: Smaller Packages & Higher Integration
Higher Density: Smaller Packages & Higher Integration

• **Trends:**
  - Increasing electronics content in cars.
  - Constant-size or smaller cars.

• More electronics in the same or less space: **higher density is required.**

• Smaller packages and higher integration
  - **Finer pitch** i/o & multi-row i/o
  - Multi-die packages / **SiP**
  - **Known good die**
  - Design for test
Freescale Impact Detection Sensors: Size Trend

- **70% shrink** over 13 years.

- **Automotive safety function:**
  - XY, and Z-axis over-damped transducer
  - Control / logic / signal conditioning die

- **Packaging solution:**
  - Multi-die package
  - Stacked die QFN
  - AEC Grade 1
Increasing Integration: Automotive System in Package

Today’s System in Pkg Solutions

- Side-by-side die in leaded and leadless packages
- Stacked die in leadframe and substrate packages

Future System in Pkg Solutions

- Die-to-die interconnect plus wire bond
- Multi-die 3D fan-out
- Multi-die flip chip
Automotive Electronics
Packaging Implications

Higher Density: Higher Ambient Temperatures
Higher Density: Higher Temperatures

• More electronics in less space:
  - Closer spacing of components.
  - Moving components closer to engine and transmission.
  ➔ Higher ambient temperatures.

• Electronics requirements
  - Extended hours at high temperature operation requires more robust materials and assembly processes.
  - Deeper temperature cycles in use case requires higher board-level reliability.
## Automotive Packaging Reliability Requirements

### DIS
- Grade 3 & 2
- -40°C to +105°C

### Chassis & Safety
- Grade 1
- -40°C to +125°C

### ADAS
- Grade 1
- -40°C to +125°C

### Body
- Grade 1
- -40°C to +125°C

### Powertrain
- Grade 1 & 0
- -40°C to +150°C

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<th>Package STRESS</th>
<th>ABV</th>
<th>TEST METHOD</th>
<th>Duration</th>
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<td>Standard</td>
<td>Condition</td>
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<td>TC</td>
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</table>
Packaging 101: Everything Matters

- Every component and interface in the package must be carefully engineered.

Packaging Materials

- Epoxy Mold Compound
- Substrate or Leadframe
- Die Attach

Mechanical Connections

- EMC to Top of Die Surface Adhesion
- Die to Die Attach Adhesion
- Die Attach to Solder Mask Adhesion
- EMC to Solder Mask Adhesion
- Die Attach to Cu Leadframe Adhesion
- EMC to Ag plating Adhesion
- EMC to Cu Leadframe Adhesion

Electrical Connections

- Wire Bonds (Cu / Au)
- Cu Traces or Cu leads
- Solder Joints

Focus: wire bond reliability at high temperature.
Improved Reliability with Copper Wire vs. Gold Wire For High Temperature Performance

- Comparison: high temperature storage life.

- Cu wire reduces interface voids and related AEC grade 0 issues.
- Now in production and plan-of-record for all Freescale automotive parts.
Automotive Electronics
Packaging Implications

More Components: Lower Cost & Higher Reliability
More Components: Lower Cost

• As electronics content in cars increases, **downward price pressure** results.

• Typical industry solutions:
  – Die shrinks
  – Efficiency improvements
  – Outsourced manufacturing

• **Packaging cost levers:**
  – Materials (e.g. **Au to Cu wire**)
  – I/O pitch reduction → body size reduction
  – Package platform selection

Source: Strategy Analytics (Jan’14)
More Components: Higher Reliability

- Vehicle manufacturers continue to drive for **improved reliability** and lower warranty costs **per vehicle**.

- Delivering this while greatly increasing the number of electronics components per vehicle means that **per-component reliability must dramatically improve**.

- **Packaging implications:**
  - Fundamental reliability: better engineering
  - Enhanced manufacturing controls

*Analysis based on data from Strategy Analytics (Jan’14)*
Better Reliability through Better Engineering & Control

• Reduced Empiricism
  - Empirical data alone are insufficient to guarantee success. Sample sizes are ultimately too small.
  - The chemistry / math / theory also has to be right.

• Materials Selection
  - Nuances abound! Fundamental to reliability.

• Mechanical & Thermal Design & Modeling
  - Necessary path: from descriptive to predictive.

• Electrical Design & Modeling
  - Reliability often requires extensive co-design.

• Assembly Process Development
  - Robust process windows support mfg. stability.
  - Compliance and repeatability are key!

• Manufacturing Controls
  - Discipline & consistency: growing importance.
Summary

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