Greetings from Georgia Tech PRC

Packaging for Autonomous Vehicle Electronics
Application and Market Projections
ECTC – May 31, 2017

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Source for some slides: Prof. Rao Tummala, GT PRC Director
3 Main Reasons for Automotive Electronics

1. Reducing Human Fatalities
   - 94% of 33,000 Deaths in the U.S., and 1.3M globally due to human error

2. Improving Driving – Energy Efficiency

3. Improving Human Productivity

*Many, Many more*

Mercedes-Benz F 015 Luxury in Motion Research Car
Key Drivers for Automotive Electronics

Computing - Autonomous Driving

Connectivity (4G, 5G)

Sensing Electronics
- Radar
- Lidar
- Cameras

Electric & Hybrid Drivetrains
- Batteries
- Drive Train & Battery Charger
- Power Distribution & Power Conversion

Automotive Systems may be the first to introduce several new device and packaging technologies (e.g. LIDAR) in high volumes
Automotive Market Projections for IC consumption are Accelerating

IC End User Markets ($B) and Growth Rates

- Cellphone: $74.2
- Automotive: $22.9
- Standard PCs: $54.6
- Servers: $15.1
- Digital TVs: $12.9
- IOTs: $12.8
- Game Consoles: $8.9
- Tablets: $12.1
- Set Top Box: $5.7
- Medical: $4.9

Share of 2016 IC Sales

- Automotive Electronics: 22% YoY Change in 2016

2015-2020 CAGR

Source: IC Insights

* Covers only the Internet connection portion of systems

Source: IC Insights
Levels of Autonomous Driving

- **Level 1** – Function-specific Automation: Automation of specific control functions, such as cruise control, lane guidance and automated parallel parking. Drivers are fully engaged and responsible for overall vehicle control (hands on the steering wheel and foot on the pedal at all times).

- **Level 2** - Combined Function Automation: Automation of multiple and integrated control functions, such as adaptive cruise control with lane centering. Drivers are responsible for monitoring the roadway and are expected to be available for control at all times, but under certain conditions can disengaged from vehicle operation (hands off the steering wheel and foot off pedal simultaneously).

- **Level 3** - Limited Self-Driving Automation: Drivers can cede all safety-critical functions under certain conditions and rely on the vehicle to monitor when conditions require transition back to driver control.

- **Level 4** – Self-Driving Under Specified Conditions: Vehicles can perform all driving functions under specified conditions.

- **Level 5** - Full Self-Driving Automation: Vehicles can System performs all driving functions on all normal road types, speed ranges and environmental conditions.

- Several OEMs have pledged to include Level 1 Functions to be in all cars sold by 2022
- Level 2 available in most luxury vehicles in 2017 model year
- Level 2 as a Standard feature in several 2017 models

Source: NHTSA 2013
Move to Autonomy is Happening

Adapted from: Dave McNamara, Magna

- Lane departure prevention
- Park assist
- Rear traffic alert
- Drowsiness detection
- Collision mitigation
- Blind spot mirror
- Rear cameras
- Traffic Jam Assist
ADAS is Highly Heterogeneous
Requiring SOP Concept

Technologies

- RADAR
  - ACC
  - Brake Assist

- LIDAR
  - Blind Spot

- Ultrasonic
  - Park Assist

- Camera
  - Lane Assist
  - Pedestrian Det.
  - Mono
  - Traffic Sign Rec.
  - Stereo
  - Auto High Beam
  - ToF
  - Dynamic Lighting
  - IR
  - Surround View
  - Night Vision

- Map Data
  - Navigation

- V2V/V2X etc.
  - Telematics

ECU

Collision Mitigation

- Sensor Fusion

ADAS Domain Control

Highly automated driving by sensor fusion

Source: Strategy Analytics

2010

2015

2020

Courtesy: Dave McNamara, Magna
Venky Sundaram, Georgia Tech
Integration of Multiple Packaged Devices for Semi-Autonomous Functions

- **Auto Emergency Braking**
  - Front RADAR (packaged in FO WLP)
  - Front Camera (Ceramic or organic package with embedded ISP)

- **Lane Keeping or Centering**
  - Dual lane watch cameras (increasing to 3 or more in future)
  - Electric steering assist

- **Adaptive Cruise Control**
  - Front RADAR
  - Front Camera

- **Self Parking System**
  - 12 ultrasonic sensors
  - Surround view (4 cameras)

- **More than 40 processors controlling Level 1 functions**
Connectivity & Data Bandwidth

- Average Connected Car – 4000 GB per day
- Average Person (video, chat and internet usage)
  - 650 MB in 2016
  - Expected to grow to 1.5GB by 2020

Source: Brian Krzanich, Automotiility 2016
Two Reasons For Electric Cars: Sustainability and Efficiency

Source: Ford Motor Company
WBG Power Devices & Modules

WBG Devices
- High operating temperatures
- High frequency operations
- Lower switching losses
- High power density

- Elimination of liquid cooling
- Reduction in heat sink size
- Smaller physical size of passives (L, C, transformer)
- Improved power efficiency
- Smaller footprint

**Source:** Keysight / APEC 2015

Toyota announced introduction of SiC Devices for drivetrain within the next five years

Goal: 80% less volume

**Source:** Toyota

→ Need packaging solutions FOR GaN / SiC

**Source:** Toyota

**Courtesy:** Dr. Vanessa Smet, GT PRC
Summary

- Automotive Electronics market introducing several new functions requiring new device and packaging technologies

- Driving functions are
  - Autonomous driving (sensors and computing/AI)
  - Connectivity and infotainment
  - Electric and Hybrid Drivetrains
Thank you
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