Industry Consortium for New Era of Automotive Electronics with Entire System-on-Package Vision at Georgia Tech

Rao Tummala*, Klaus-Juergen Wolter, Venky Sundaram, Vanessa Smet, Pulugurtha M. Raj

3D Systems Packaging Research Center, Georgia Institute of Technology, Atlanta, USA

Rao.tummala@ece.gatech.edu

Abstract

The new trends in automotive electronics such as autonomous driving, in-car smartphone-like infotainment, privacy and security, and all electric cars, require an entirely different vision than is pursued today. Georgia Tech sees unprecedented challenges and opportunities to address these needs because of disparate set of technologies that hitherto fore thought to be impossible to integrate. It proposes a systematic approach to system scaling, heterogeneous integration and innovative package architectures as the new era in electronics hardware with particular focus in electrical, mechanical and thermal designs and new digital, RF, sensors, millimeter wave and power technologies. The Georgia Tech team proposes a transformative and yet a strategic approach to automotive electronics, called System Scaling, leading to entire automotive system-on- a package. Such a system must integrate many disparate technologies such as high speed digital, optical, RF and wireless sensing and data processing from 100s of sensors as well as ultra-high power electronics. Georgia Tech proposes a highly innovative large panel-based, ultra-thin glass packaging in 3D double-side architecture with many, many innovations in designs, materials, processes, wiring lithography, fine-pitch and highly conductive through-vias for thermal management and system integration. Such an approach is proposed to lead to highly-functional systems with disparate set of technologies at lowest cost, in smallest ultra-miniaturized size with shortest interconnections with lowest power consumption. Georgia Tech views this approach to be superior to current approaches such as chip-first or wafer fanout or chip-last organic, leadframe and molded packaging technologies.

1. Introduction

Georgia Tech, as the largest engineering university, the home for one of the largest electronics research clusters and with number-one-ranked technology programs in manufacturing and in electronic Packaging in the U.S., proposes a highly-integrated and transformative electronics systems technology consistent with the new era in automotive electronics that includes autonomous driving, secure and high speed communications and all-electric cars. It has already attracted many automotive companies to develop R&D and educational programs. To date, Georgia Tech has strategic partnerships with three major automotive companies that include: BMW, GM and Ford.

These automotive companies consider Georgia Tech to be their "top tier" partner institution, resulting in a relationship that is deeper and wider in its reach and impact. In addition, active research is currently underway with Mercedes Benz, Ferrari, Honda, and Toyota in many areas that include hybrid vehicle R&D, Internal component design, Communication-vehicle interactions, automated driving, driver-assist, human-robot interactions as well as in environmental and ecological impacts.

Based on these partnerships, faculty expertise in many required core technologies, extensive facilities and successful industry consortia in system integration involving many faculty and entire supply-chain of manufacturers and users in consumer electronics, Georgia Tech proposes to extend its current industry consortium to a Global Automotive Industry Consortium for new era of automotive electronics..

2. Trends in automotive electronics

Automotive are becoming "Electronic Devices," unlike in the past, mainly, as mechanical devices. Automotive electronics are expected to account for about a third of the total cost of the entire car, about $10,000 for each car. This is a huge market. The proposed industry consortium is consistent with three major new drivers in Automotive Electronics: 1) autonomous driving, 2) secure and high speed communications and infotainment, 3) all-electric cars. It is also consistent with the trends such as:

- Increased electronics content in cars without increasing the size of the cars thus allowing more electronics to occupy the same or less space requiring further miniaturization beyond current packaging approaches;
- Integrated electronics with 100s of sensors and computing electronics that are necessary to process the information;
- All-electric vehicles that require ultra-high battery power that is efficient and light-weight electric components for electric motors, inverters, converters, control and driver electronics and high-voltage batteries;
- Data security and privacy.

ISBN 978-0-9568086-2-2

2.1. Autonomous driving

The journey to autonomous driving has already started with the development of collision-avoidance sensors requiring a new era in connectivity to infrastructure, as shown in Figure 1.

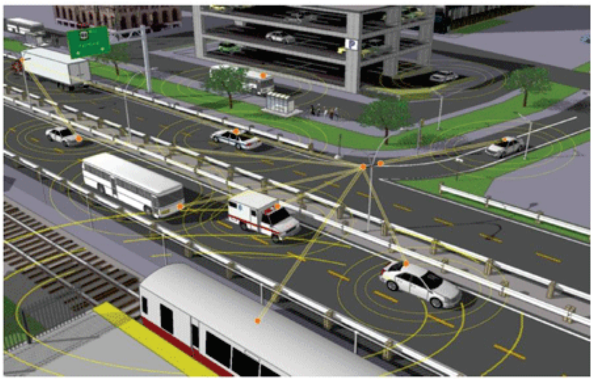


Figure 1: new era in automotive electronics – connectivity to infrastructure [1]

Google's self-driving cars are reported on the road in several states [2]; Tesla announced that its cars will be fully autonomous in three years [3]; and Uber has opened a test facility in Pittsburgh [4] to develop an autonomous taxi fleet. In addition, the regulatory framework for testing and operation of autonomous vehicles on public roads was already established in California. European car makers predict that the implementation of highly-automated self-driving cars will start in 2020 [5]. Autonomous driving technologies have progressed rapidly in recent years due to the advancements in vehicle sensors and communication technologies. These advancements have led to better visibility and awareness – around the vehicle – and to features such as park assistance, adaptive cruise control, lane-keep assistance, traffic-sign recognition and pedestrian detection, as illustrated in Figure 2.

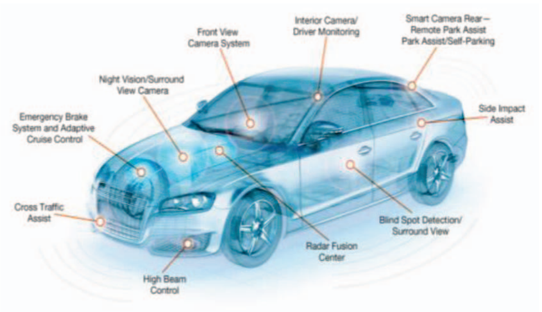


Figure 2: Advanced Driver Assistance Systems (ADAS) application example [6]

2.2. All-electric cars

Automated driving also brings simultaneous development and introduction of more environmentally-friendly propulsion techniques, using alternative energy. The powertrain electrification trend in all-electric and hybrid vehicles is picking up speed at every major automotive company and is expected to account for more than 10% of the market share in the next five years and growing faster in the next two decades.

Figure 3 illustrates the three critical component technologies in electric cars that include inverter, battery charger and battery itself to be designed and developed to serve this market.

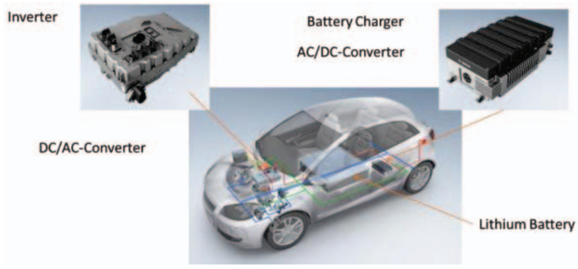


Figure 3: new era in automotive electronics – powertrain of electric vehicles

2.3. Secure, high-speed and infotainment electronics

All the electronic advances that are currently used in smartphones, are being enhanced and planned to be used inside the car, particularly as self-driving cars become a reality within a decade. Apple is reported as focusing on CarPlay [7], its in-car infotainment system that integrates iPhone features, like messaging, music and maps into a vehicle's dashboard. It appears that every major auto brand is committing to use CarPlay.

3. Georgia Tech vision for automotive electronics

Semiconductor, packaging and systems landscape is changing dramatically. These changes will have a great impact on emerging automotive electronics. For example, ICs, on one hand, for the most part, are becoming commodities, providing much lower profit margins than ever before, leading to industry consolidation to less than five companies within the next decade, worldwide. In addition, the cost and complexity of transistor scaling is growing exponentially. There is no longer a cost reduction as the next node is introduced with higher transistor density. The driving engines for electronic systems, on the other hand, are also changing dramatically to smart, wearable, wireless sensors and wireless networks and emerging self-driving, smart and all-electric cars, requiring an entirely different vision and strategy than transistor-scaling alone that has been practiced during the last 60 years. These systems must perform dozens of functions that include wireless communications; wireless sensing, stereo cameras, mm-Wave electronics, high bandwidth electronics or Photonics for data processing with data security for autonomous driving; and high power and high temperature electronics for all-electric cars.

ISBN 978-0-9568086-2-2

0Integration of all these into a single package is more than Moore's Law, with on-chip transistor integration and, lot More than Moore's Law (MTM) with stacked heterogeneous integration or SIP. It is System Moore's Law (SM) for complete system integration, leading to “A-SOP”, (Automotive System-on-Package) with a market size as big as all the electronics to date.

Such a vision is shown in Figure 4, leading to the entire automotive electronic system-on-package (A-SOP) with all the functions necessary for the car. Georgia Tech proposes a modular and incremental approach to evolve to A-SOP over the next decade. It involves 10 basic or core technologies, as listed in the first column of Figure 4 to be explored and demonstrated. Those that are successfully demonstrated move on to form design and demonstration test vehicles, demonstrating functional modules. Some of these to date are digital modules, photonic modules, RF modules, and power modules. The new ones to be added include high-temperature and, high-power, sensor arrays and communication electronic modules.

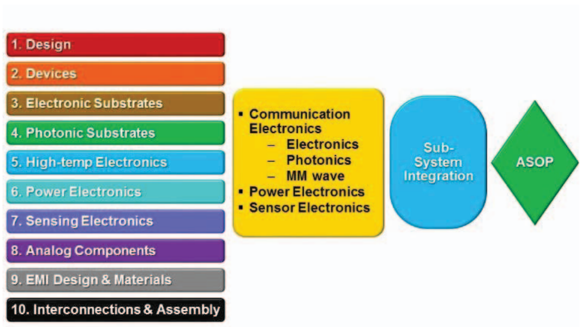


Figure 4: Georgia Tech approach from 10 core technologies to functional modules to system Integration to A-SOP

4. Systems Scaling and Integration (SSI) industry consortium for automotive electronics

The proposed SSI industry consortium is very different from current approaches for automotive electronics in both technologies and in partnerships with the industry. It is a co-development with global industry, involving manufacturing supply-chain companies, semiconductor, package, assembly and automotive system companies.

The fundamentals of SSI:

- Short interconnect length for highest performance
- Ultra-low loss substrates and dielectrics for minimum power consumption in interconnections
- Ultra-low loss substrates and dielectrics for high frequency (mm-Wave), and data-secure communications
- Low-dielectric constant dielectrics for high signal speed
- Through TSV-like vias at fine-pitch for double-side interconnections and assembly of actives and passives to form 3D Packages at same as TSV pitch for miniaturization and performance
- Thick Cu ground planes and large Cu through-vias or slugs for high-thermal dissipation
- Large panel (510mm) manufacturing for lower cost than 300 mm wafers
- High-performance capacitors and inductors for power
- High-temperature substrates, passives, and interconnections for high-reliability.

Such a strategy over the next decade is expected to close the gap between transistor scaling and system scaling that exists today, as illustrated in Figure 5, resulting in System Moore as illustrated in Figure 6. The manufacturing foundry for SSI must be large panel-based to produce and assemble low-cost and ultra-small automotive modules, sub-systems and systems.

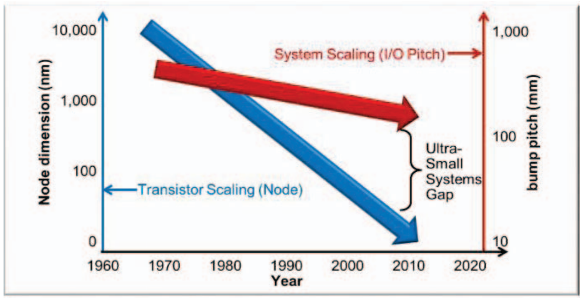


Figure 5: gap between transistor and system scaling for electronics systems

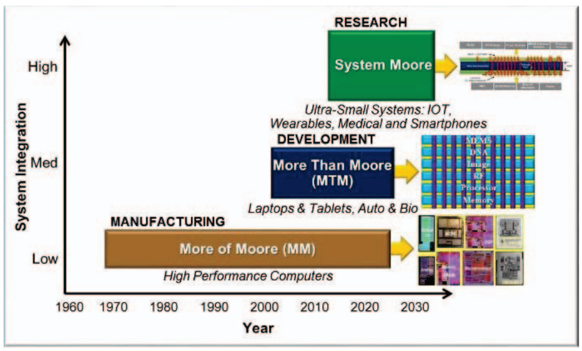


Figure 6: System Moore with the 3D System-on-Package for all systems functions in one package

Georgia Tech proposes to enhance its current Industry Consortium that is already a broadly-participated, pre-competitive, industry-led and industry-funded R&D consortium involving about 50 companies in materials, tools, substrates, and assembly as well as semiconductor and systems users, as shown in Figure 7.

ISBN 978-0-9568086-2-2

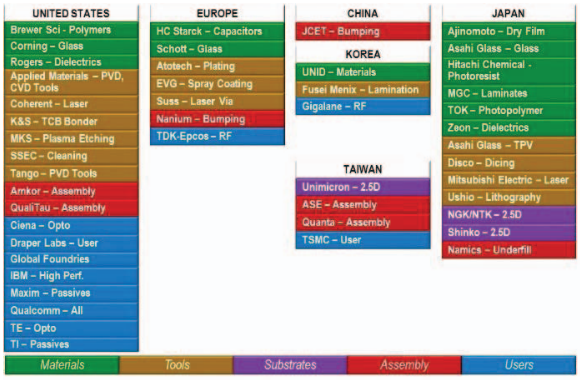


Figure 7: current Georgia Tech Industry Consortium in heterogeneous electronics

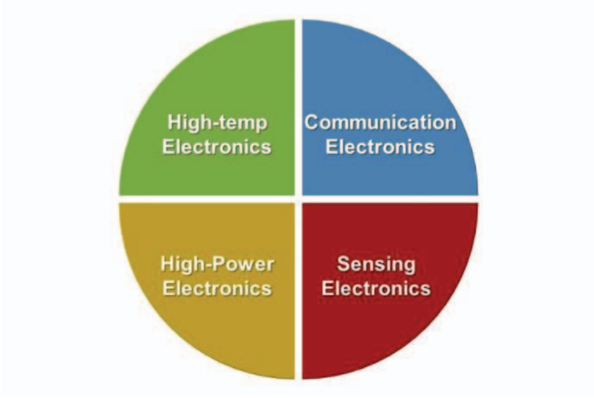
5. Industry consortium R&D areas

The proposed SSI for automotive electronics is based on highly integrated, miniaturized, highly-reliable and low-cost modules, sub-systems and systems to perform four primary functions as shown in Figure 8, that include::

1. Communication Electronics
    a. Dedicated short-range communications (DRSC)
    b. Computing for fast and safe navigation
2. Sensing Electronics
    a. Smart internal-state sensing
    b. Environment and navigational sensing (lidar, radar, ultra-sonic, video camera, GPS)
3. High-power Electronics
    a. Energy efficient smart power modules
    b. Packaging for SiC and GaN power modules
4. High-temperature Electronics
    a. High-temperature driver modules
    b. High-temperature sensor and actuator electronics

The proposed research projects within each of these are:

- Communication Electronics
    - Digital, RF and mm-Wave electronics
    - Mixed signal electrical design
    - mm-Wave Glass module
    - 3D Package for high bandwidth
    - 3D Glass photonics
    - EMI shielding
- MEMS and Sensor Electronics
    - Miniaturized wireless 3D-Glass BGA sensor interface
    - Packaging platform for sensor arrays
    - Camera electronics
    - Packaging platform for sensor fusion
    - Sensor packages for high ambient temperatures
- High-power Electronics
    - Control and safety electronics
    - High-power modules
    - Thermal technologies
    - Power module reliability
- High-temperature Electronics
    - High-temperature glass substrates
    - High-temperature interconnects
    - High-temperature passives
    - High-temperature encapsulation



•

Figure 8: Georgia Tech focus on four areas of automotive R&D

6. Summary

The new era of automotive electronics requires new transformative fundamental and integration technologies. Georgia Tech sees unprecedented challenges and opportunities for system integration of many disparate technologies that hitherto fore thought to be impossible. It proposes system scaling, heterogeneous integration and innovative package architectures as the new frontiers with particular focus in electrical, mechanical and thermal designs; new, digital, RF, sensors, mm-Wave wave and power technologies. The Georgia Tech team proposes a transformative and strategic approach to automotive electronics, called System Scaling, leading to entire automotive system on a package. The approach will be modular and incremental over a decade of exploration and demonstration.

ISBN 978-0-9568086-2-2

Literature

[1] D. Newcomb, "Autonomy and V2V will Coexist Not Compete," C3 Report, 2014 [online]. Available at: http://www.cthreereport.com/category/vehcile-to-vehicle-communication/.

[2] D. Newcomb, "Google Takes Self-Driving Car Testing to Texas," Forbes, 2015 [online]. Available at: http://www.forbes.com/sites/dougnewcomb/2015/07/14/google-takes-self-driving-car-testing-to-texas/.

[3] J. Hirsch, "Tesla CEO Musk: Some Mosel S owners to get hands-free steering," Los Angeles Times, 2015 [online]. Available at: http://www.latimes.com/business/autos/la-fi-hy-tesla-shareholders-meeting-musk-20150609-story.html.

[4] J. Coyne, "Exclusive: Here's your first look at Uber's test car (and why you'll see it around Pittsburgh)," Techflash, 2015 [online]. Available at: http://www.bizjournals.com/pittsburgh/blog/techflash/2015/05/exclusive-heres-your-first-look-at-ubers-self.html.

[5] J. Dokic, B. Muller, and G. Meyer, "European Roadmap Smart Systems for Automated Driving," European Technology Platform on Smart Systems Integration, 2015 [online]. Available at: http://www.smart-systems-integration.org/public/documents/publications/EPoSS%20Roadmap_Smart%20Systems%20for%20Automated%20Driving_V2_April%202015.pdf.

[6] Staff, "Advanced Driver Assistance Systems (ADAS)," Freescale, 2015 [online]. Available at: http://www.freescale.com/webapp/sps/site/overview.jsp?code=ADAS.

[7] J. Rivington and M. Swider, "Apple CarPlay: everything you need to know about iOS in the car," Techradar, 2015 [online]. Available at: http://www.techradar.com/us/news/car-tech/apple-carplay-everything-you-need-to-know-about-ios-in-the-car-1230381.