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Detroit Three EEs Consider Architectural Upgrades

Last month at the sparsely attended SAE 2016 Convergence conference, one panel session caught my attention. The subject was the future of the car’s electrical architecture. **General Motors, FCA and Ford** were well represented, and the panelists provided strong indications of what changes to expect in their next-generation architectures.

The panel’s keynote was delivered by Alberto Vincentelli, professor of electrical engineering and computer science at the University of California at Berkeley. Among his assertions were these:

- Automation is forcing an overhaul of architecture.
- Functionality will be decoupled from architecture.
- While CAN is fine for some applications, it won’t be used as the vehicle’s backbone. Because it is slow and asynchronous it can’t guarantee safety and reliability. Ethernet will provide the backbone.
- There is no single best architecture. Future architectures will be combinations of distributed computing and centralized computing functions connected to the cloud. “You can’t do sensor fusion in a single processor,” noted Professor Vincentelli.

Big changes are coming as carmakers leverage vehicle connectivity and the cloud to provide safer driving and autonomy. As vehicle architecture goes, so goes the market for a host of automotive electronics components. There will be some winners and some losers.

**Networks**

In networks, the winner will certainly be Ethernet. The loser is FlexRay. There was wide agreement that a safety-critical version of Ethernet will handle backbone traffic, namely Time Sensitive Networking (TSN). An extension of the Audio Video Bridging (AVB) standard, the TSN standard is focused on applications that require safety and hard real-time control to enable backbone architectures and failsafe operational systems such as ADAS and autonomous driving. TTTech, with its estimable safe networking expertise, has been a key player in helping to make Ethernet deterministic.

Apart from safety-critical applications, Ethernet is also being considered for IVI and vision systems, according to Doug Thornburg, advanced architecture design supervisor at Ford.
FlexRay, the safety-critical protocol pioneered by Mercedes and BMW, has been applied by some carmakers, but not universally. The pace of adoption beyond the Germans might be called glacial. “The use of FlexRay has pretty much disappeared,” said Rick Flores, GM Technical Fellow, electrical systems/software engineering. “The addition of timing capabilities to Ethernet now makes that a much more suitable choice.” Rob Rudzewicz, responsible for EE architecture and integration at FCA, agreed. “We are not actively pursuing FlexRay.”

While it is slow compared with Ethernet and not deterministic, CAN, the universally applied network technology invented by Bosch, still has plenty of legs. “We will continue to benefit from CAN for efficient communications with smart sensors and smart actuators. CAN is a completely sufficient, viable and familiar standard that we can implement with high confidence with a very large component base,” asserted Scott Morrison, engineering group manager at General Motors. CAN FD (flexible data-rate CAN) also drew support from the GM, Ford and FCA panelists. LIN, the inexpensive, single-wire serial multiplexing bus, is also still widely supported.

Central Computing
In June 2016, the Hansen Report looked at the development by Audi and BMW of central computing architectures calling for one or more general-purpose, high-performance, water-cooled computers powered by extremely capable processors from suppliers such as Nvidia and Qualcomm. The German carmakers indicated that today’s distributed architecture is outmoded, and that a revolutionary new architecture is needed to support automated driving.

Speaking during the Convergence panel, GM’s Mr. Morrison expressed support for central computing. “A central compute platform is a very interesting architectural alternative that we haven’t aggressively pursued, but it is something we need to challenge ourselves to consider more consistently across the board. It gives us a much more inherently fault-tolerant architecture with a significantly more flexible hardware platform that allows us to abstract functionality.”

This summer we checked in with Nvidia’s senior director of automotive, Danny Shapiro, to see how much support centralized computing was getting. “We are engaged with over 80 different companies with the centralized-supercomputer-for-car concept, our Drive PX platform. That
includes automakers, tier ones, transportation business startups, as well as a number of research institutions. By all means, the focus is on massive amounts of computing in the car and centralizing it. If you talk to anybody who would be creating a new car from scratch, they are not going to design in 100 ECUs.”

Regardless, Ford’s Mr. Thornburg indicated that his company will not be joining the OEMs adopting a central computing platform any time soon. “Redundancy requirements and functional safety requirements alone pretty much preclude that,” he said. “We are taking the distributed approach.”

FCA isn’t sold on the central computing platform either. “I don’t think there will be one ECU for automated driving. It is certainly a network of high-compute type platforms working together,” said Mr. Rudzewicz.

**Microprocessor Suppliers**

Regardless of the balance between central and distributed computing, the demand for computing resources is multiplying, and that has attracted some relatively new suppliers including **Nvidia** and **Qualcomm**. Indeed, according to reports, Qualcomm is negotiating to acquire **NXP**, **Intel**, which has shown off-and-on interest in the automotive industry, is again showing interest. Korean supplier **Samsung Electronics** last year announced its new focus on the automotive electronics market. Japanese mobile communications and Internet provider **SoftBank** is buying chip designer **ARM Holdings**, whose embedded architectures have been widely used in automotive applications for years. ARM’s CEO was quoted in February by CNBC saying that ARM sees the potential for a hundred times growth in computing power in cars.

“All kinds of suppliers who a few years ago were not looking at the automotive space all of a sudden became interested because they see opportunities for connectivity, advanced guidance and autonomous driving systems,” said Mr. Thornburg. “It has also spurred some traditional players to up their game. All those things we had on our drawing board and never realized we can now consider, because the cost of compute and memory is much better than it used to be.”

“Compared to ten years ago, [microcontroller] suppliers are considerably more aggressive now, offering new technologies,” said
Mr. Rudzewicz. “It is not a given that the companies that just got into the market will inherently win business. There is a lot of knowledge at the traditional ones. They are all excited now.”

**V-Model Testing Antiquated**
Among the many changes in store for the automotive electronics industry, the familiar V software development model may be going away in favor of Agile development approaches, which are more iterative. The V-model worked well when the car’s product plan was not subject to change post-sale. “New functions will be deployed after job one,” said GM’s Mr. Morrison. “We have to learn how to quickly react to constantly changing customer expectations, and do that in the face of ongoing cybersecurity challenges. We must use more Agile tools and methodologies.”

**Future Proofing**
Carmakers are more inclined today than in the past to build computing and memory headroom into their architectures so vehicles can receive software updates to fix bugs, firm up cybersecurity defenses and provide new features. “A big challenge, however, will be insuring that the update is compatible with past versions going back several model years,” cautioned Mr. Rudzewicz.

Despite the call for more headroom, cost will continue to be a limiting factor. “At the beginning of every architecture journey that I have been part of, whatever the proposal, it is always seen as too expensive and too extensible,” cautioned Mr. Morrison. “At the end of the lifecycle of an architecture, it is always clear to everyone that it is not capable enough, not scalable enough, not future proof enough, and that is why we need a new one.” Hardware updates to the vehicle post-sale are not yet envisioned.

**Accommodating Computing in the Cloud**
Connected vehicle architectures will increasingly rely on computing assets in the cloud. Music streaming, navigation and speech interfaces are already supported in the cloud. Data analytics are also cloud based. “But since cellular coverage can’t be guaranteed everywhere, functional safety requirements will keep us from running anything that is mission critical in the cloud for quite a while,” cautioned Ford’s Mr. Thornburg.
Surprise: Volkswagen Leans Toward SDL

Volkswagen has been the chief advocate for MirrorLink, the device and app connectivity solution initiated by Nokia in 2010. But recently I learned that Volkswagen has been working to integrate SmartDeviceLink into MIB III, its third-generation modular infotainment platform, which will be introduced this coming January at 2017 CES.

MIB II—which spans most Volkswagen products and supports four different head units depending on trim level—was introduced in 2014. It integrates Apple CarPlay, Android Auto and MirrorLink solutions.

With this information about MIB III in hand, I checked in with Volkswagen’s top electrical engineer, Volkmar Tanneberger, who wrote that, “Volkswagen is currently evaluating SDL. There is no decision yet. SDL is a technology with great potential to enhance the customer experience. [Its] deep integration into our infotainment systems provides a holistic user experience. However, at this point there are still some improvements to make; e.g. the impact on system performance needs to be kept low. Also, for seamless integration, the startup procedure on the phone side needs to be tweaked a little bit.”

What happens now to MirrorLink? Dr. Tanneberger explained: “Independently of the pending decision regarding SDL, VW will support MirrorLink in future models and continue its engagement in the Car Connectivity Consortium. Volkswagen’s strategy is to support our customers whichever way they prefer to access their apps and services.”

According to reports, Volkswagen has also embraced Baidu CarLife, the Chinese-specific alternative to Apple CarPlay and Android Auto.

SDL is gaining broad support. Ford and Toyota are committed to the solution while PSA, Subaru, Honda and Mazda are actively investigating SDL. However, Matt Schroeder, a top EE executive at GM, said that GM is not onboard with SDL.

The template approach of SDL allows OEMs to maintain their brands’ look and feel with a customized user experience. Andrew Poliak, vice president product planning and business development for Panasonic Automotive Systems, noted another key benefit: “With more exposure to the car’s functions, apps based on SDL could be tailored to be more automotive centric than apps based on projection modes, for example, CarPlay or Android Auto, which are video projections of a standardized automotive application experience.” With more carmakers adopting SDL, the potential market for automotive-specific apps will grow, as will the community of automotive app developers. ◆
Rethinking EDRs for Autonomous Vehicles

While event data recorders are not required in the United States, the vast majority of vehicles sold here are equipped with them as part of the airbag control module. Federal regulations mandate that EDRs meet certain specifications. EDRs must be capable of recording at least 15 types of data, advanced EDRs record even more data. However, when it comes to automated driving, today’s EDRs are insufficient and will have to be changed.

The U.S. National Highway Traffic Safety Administration recently published guidelines for testing automated vehicles. In that policy statement, NHTSA said it believes “enhanced event data recorders would be useful to allow the Agency to reconstruct the circumstances of crashes and to gain an understanding of how a vehicle involved in a crash or incident sensed and responded to its driving environment immediately before and during the crash or near crash.”

According to a July 2016 Reuters article, “Germany plans new legislation to require manufacturers of cars equipped with an autopilot function to install a black box to help determine responsibility in the event of an accident.” According to a Department of Transport publication, the British government has a similar position, suggesting further that “data recorders would be regulated on an international basis.”

I asked the Detroit 3 architecture panelists at last month’s Convergence conference about their plans to accommodate event data recorders now that autonomous driving is upon us. Scott Morrison, engineering group manager at General Motors, likes the idea of international standards for event data recorders: “It would be very helpful to have very clear requirements.”

“Today every OEM has slightly different requirements for functions,” said Rick Flores, GM Technical Fellow, electrical systems/software engineering, who sees standards as “an opportunity to define standard interfaces for functions.”
Doug Thornburg, advanced architecture design supervisor at Ford, said Ford pictures an autonomous driving EDR as a separate box from the existing event data recorder, with a communication path sufficiently wide to carry all the information required by autonomy.

Rob Rudzewicz, responsible for EE architecture and integration at FCA, agreed. “As autonomy grows up we will need to figure out what information needs to be recorded. Given the sheer amount of information to be stored, the communications bandwidth and latency issues, the EDR will likely be part of the autonomous solution, not part of the present EDR.”

Governments will almost certainly propose requirements for event data recorders in vehicles that feature automated driving. Since the biggest beneficiaries of EDRs will be the carmakers and their development partners, there will probably be little pushback from them against government mandates. Information gleaned from EDRs in crash and near-crash events will be used to further automated driving technology and ultimately safer transportation.

Another benefit to carmakers, EDRs will be used to determine liability when crashes occur. Was it caused by a malfunction of the vehicle’s autonomous technology? Or was another vehicle or the roadway the cause? Or was driver negligence the cause—a question that is relevant to Level 2 and Level 3 automation, which require monitoring by the driver. EDRs will limit carmaker’s uncertainty regarding the cost of liability, improving the business case for autonomous vehicle development. ♦
The Company Profile: Hella KGaA Hueck & Co.

Thumbnail Sketch
Headquarters: Lippstadt, Germany; www.hella.com
FY 2016 Sales: €6,352 million
R&D: 9.8%
Interest Expense: 0.5%
EBIT Margin: 6.6%
Net Cash from Operating Activities: €602 million
Working Capital: €1,330 million*
Net Debt: €238 million
Non-Current Liabilities: €1,657 million*
Equity: €2,033 million*
Market Capitalization: €3,949 million as of October 4, 2016
Employees: 33,689, of whom 6,361 work in R&D, as of May 31, 2016
Sales per Employee: €188,548
Major Products: Headlamps, radar, position sensors, electric vacuum pumps, battery sensors, and turbo actuators
Major Customers: VW Group, GM, Mercedes, BMW and Ford, among others
*As of August 31, 2016

Hella’s fiscal year ends on May 31.

Distinctions Claimed by the Company
- World market share leader in rear-facing 24 GHz radar sensors: 10 million units produced as of August 2016
- The world’s first series production of LED headlamps, in 2008
- The world’s first series production of Matrix LED electronically controlled headlamps, no mechanical actuators required, in 2014
- Hella’s Multibeam headlamp, another world’s first, supplies precise high and low beam lighting using 84 individually controlled LEDs.
- Number-one supplier of battery sensors in Europe, number-two in Asia, and soon, number-one in North America: 10 million units sold annually

The Hansen Report on Automotive Electronics, October 2016
www.hansenreport.com
Background
The company was founded as Westfälische Metall Industrie in 1899 in Lippstadt, Germany, where Hella continues to operate its headquarters. The first factory specialized in the production of lanterns, headlamps, horns and fittings for bicycles, carriages and automobiles. In 1908 the founder trademarked the name Hella for an acetylene headlamp that incorporated lenses and mirrors. In 1923 the majority of the company was acquired by the Hueck family.

Hella was restructured as a KGaA (partnership limited by shares) in 2003, which gave the company access to capital markets. The company was taken public in November 2014, and its shares are traded on the Frankfurt Stock Exchange. It remains under the control of the family, who pledged to hold 60% of the shares until at least 2024.

Hella’s goal is to deliver 30% of consolidated net profit to shareholders. Seventy percent of net profit is invested in the company. The balance sheet is strong, with an equity ratio of 40%. Within the Automotive business section are two divisions, Lighting and Electronics. Hella endeavors to be among the top three suppliers by market share in each of its product lines.

In its 117 year history, Hella has primarily grown organically, not via acquisitions. With 134 facilities in 35 countries around the world, Hella counts its global manufacturing footprint among its competitive strengths as it continues to grow a customer base in both the premium and volume segments of the OEM market.

The Hansen Report on Automotive Electronics, October 2016
www.hansenreport.com
“We are investing where the growth is coming from. We are investing where we need to complete our fixed global footprint,” said Kristian Döscher, head of global marketing for original equipment. “For lighting that was in Mexico and China. For electronics it was Brazil and China, in order to meet demand from customers in those regions.” Hella opened a new lighting products manufacturing plant in Mexico in January 2014, its fifth in the country. Four lighting plants currently operate in China, serving international and domestic OEMs.

**Lighting Business Division**

The Lighting division comprises five product segments: headlamps, rear lamps, interior lighting, small lamps and lighting electronics. Demand for halogen headlamps (commodity products) is being replaced by demand for LED headlamps, which cost considerably more. The net result: the market for headlamps (in euros) is on the rise, good news for Hella, which has spent the last decade positioning itself as an LED headlamp technology innovator.

Unit sales of LED headlamps are growing fast, at a 29% annual rate from 2015 to 2025, according to Strategy Analytics. By 2025 LED headlamps will account for 34% of the global market. LEDs are substituting for halogen headlamps, a market that Hella serves but is slowly declining, at the annual rate of 2% from 2015 through 2025.

The market for LED headlamps is growing for several reasons. They are more energy efficient than halogen and HID headlamps; they allow for more styling options; they are expected to last the vehicle’s lifetime; and their light output, typically at least 1.5 to 2

![Headlamp Penetration by Technology](image1)

![LED Market Penetration by Region](image2)

![R&D Spending by Fiscal Year](image3)
times greater than halogen headlamps, and distribution are far more controllable. Their only disadvantage is price, which is at least twice that of halogen headlamps.

“While the production of HID headlamps will continue for several years, development of the technology will soon be phased out,” suggested Michael Kleinkes, vice president of development for lighting.

Hella has a two-pronged plan to expand its LED headlamp business. While continuing development of innovative high-definition headlamps for the premium segment, Hella is expanding its range of LED-based headlamps for high-volume carmakers. Hella’s current LED headlamp customers include BMW, Mercedes-Benz and the Volkswagen Group, especially Audi and Porsche.

**LED Headlamp Innovations**

While today halogen headlamps account for the majority of the Lighting division’s sales, the main emphasis for the future is LED headlamps, a technology in which Hella has established itself as the world’s leading innovator. In 2008 Hella was the world’s first supplier to bring LED headlamps into series production, on the Cadillac Escalade.

In 2014, Hella’s industry leading LED Matrix Beam headlamps were introduced in Europe on the Audi A8. LED Matrix Beam uses camera technology to enable full-time use of high beams without dazzling oncoming traffic or the vehicle directly ahead. Each headlamp contains 25 electronically controlled LEDs to provide an almost infinite variety of light patterns while eliminating the need for mechanical parts to pivot the lamp.

Yet another large innovative step was taken in early 2016 with the introduction on the 2016 Mercedes Benz E-Class of the new Multibeam LED headlamps, a €2,350 optional feature, jointly developed with Daimler. A total of 84 individually controllable LEDs per headlamp precisely adjust the light distribution depending on traffic, weather and road conditions. Controlled by software, each LED can individually be dimmed from 100% down to zero. “This is the world’s most intelligent headlamp,” said Dr. Döscher.

Bright light is automatically distributed over the road without dazzling other road users. To further prevent dazzling oncoming traffic, when it is raining LEDs are individually dimmed to reduce the light reflected off the road surface. The light distribution of the left and right headlamps is controlled separately. The cornering light function also uses no mechanical actuators. A camera on the windscreen supplies the system with the information it needs to constantly respond to the traffic and weather situation.

The Hansen Report on Automotive Electronics, October 2016

[www.hansenreport.com](http://www.hansenreport.com)
Hella’s Matrix and Multibeam headlamp systems, which it sells in Europe and Asia, are not yet legal in the United States. Federal Motor Vehicle Safety Standard 108 still requires a means of switching between high- and low-beam lights. “We are selling a lot of LED headlamps to U.S. customers, for low and high beam, for daytime running lights and for cornering,” said Dr. Kleinkes, “but we can’t sell so-called adaptive-driving systems that rely on using the camera inside the car to detect oncoming traffic, pedestrians and bicycle riders to switch individual LEDs on and off.”

**High-Definition LED Headlamps Are Next**

As Hella’s annual report pointed out, the company is “now at the interface to light digitalization: vehicles’ external lighting will be controlled by software to a much greater extent in the future and will be digitally modulated with individually controllable lighting elements according to the traffic and road conditions.”

By 2020 or 2021, Hella will introduce its next generation LED headlamp technology. Instead of the 84 individual LEDs used in Hella’s most advanced headlamp today, high-definition (HD) headlamps will feature an array of 100,000 or more points of light or pixels, with which carmakers will be able to flawlessly paint the roadway with light. Hella is conducting research aimed at applying digital micromirror device (DMD) and liquid crystal display (LCD) technology to headlamps. Each micromirror would act as a digital light switch. The micromirror array would precisely and safely project laser light onto the roadway.

“With HD headlamps, carmakers will be able to project a navigation arrow or speed limit directly in the foreground,” said Dr. Kleinkes. “The driver won’t have to redirect his or her view away from the windshield.” Hella is already testing prototype HD headlamps on the road. One objective is to make the projectors robust enough to withstand thermal cycling, vibration and shock. In the future HD headlamps will offer a much higher resolution with a much more detailed beam pattern.

**Lighting Research**

To advance the state of the art of automotive lighting Hella will explore LCD and OLED technologies and continue to research ways to pixelate LED light sources. Another subject or research is holography. “With a holographic element in the outer lens of the rear lamp, you can create a [3D] image that provides the vehicle with an identifiable styling signature,” said Dr. Kleinkes.

**Competitive Strengths**

“We understand the whole system—the light, the electronics, the software,” declared Dr. Kleinkes. “A core Hella competence is our image processing expertise, which we use to extract information from the camera that can be acted upon by the headlamps. … Not only do we focus on the premium segment with
first of their kind applications, we are also able to serve the volume segment of the market due to our global footprint.”

Electronics accounts for half of the cost to produce LED headlamps. An electronics department operates within the Lighting division. Hella’s electronics capability extends from the printed circuit board to the ECU.

**Electronics Division**
Electronics continues to take a growing share of the vehicle’s production costs. Hella noted independent market studies that indicate electronics accounted for 30% of production costs in 2010, and that percentage will climb to 50% by 2030.

There are six product segments within Hella Electronics: actuators, body electronics, driver assistance, energy management, sensors and steering. Here we focus on three of Hella’s most promising major products.

**24 GHz Radar**
Hella is the world’s number-one supplier of 24 GHz narrow band (NB) radar sensors with a market share of more than 20%. Since 2005, when series production started, Hella has delivered ten million such sensors. Hella serves 13 carmakers, equipping more than 130 car lines with 24 GHz radar sensors. The 24 GHz sensors are produced in the U.S., Europe and Asia.

Two rear-facing 24 GHz radar sensors per vehicle provide speed, angle and distance information to objects and serve in blind spot detection, lane changing assist, rear cross-traffic alert and parking assist systems.

Hella is completing development of its fourth-generation 24 GHz sensor in time for series production to begin in mid-2017. Aimed at the high-volume segment of the automotive market, the sensor will be 30% smaller and less expensive than its predecessor. The *Hansen Report* estimates the OEM price for the two sensors will fall below 100 euros for the first time.

Much of the 24 GHz sensor is comprised of in-house intellectual property. Hella designed the antenna and the hardware and is responsible for the image processing software, the sensor’s most valuable IP. Hella uses computer simulation tools to determine how best to position the radar sensor behind the bumper to minimize interference.

Despite being in production for more than ten years, Hella still anticipates a growing market for 24 GHz sensors, especially in Europe and China. Market penetration in Europe could grow from 20% today to 40% or 50% by 2021. In
China market penetration could grow well above today’s 10%. The U.S. market is not expected to grow much beyond where it is today, at 60% to 70% penetration.

Hella competes with Valeo and Continental for 24 GHz radar business.

### Hella’s Radar Product Line

<table>
<thead>
<tr>
<th>Current 24 GHz SiGe Gen 3.0</th>
<th>Mid-2017 SOP 24 GHz SiGe Gen 4.0</th>
<th>2019-2020 SOP 77/79 GHz RF CMOS CompactRadar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body size mm</td>
<td>98 x 78 x 26</td>
<td>81 x 75 x 23</td>
</tr>
<tr>
<td>Volume</td>
<td>200 cm$^3$ (100%)</td>
<td>140 cm$^3$ (-30%)</td>
</tr>
<tr>
<td>Weight</td>
<td>&lt;170 g (100%)</td>
<td>&lt;130 g (-23%)</td>
</tr>
</tbody>
</table>

#### 77/79 GHz Radar

The next advancement in radar will come from sensors based on RF CMOS chips, which are smaller, require less power, and are potentially less expensive than sensors based on silicon germanium chips. NXP is developing 77/79 GHz CMOS radar integrated circuits, which are well suited not only to the rear-facing applications currently served by today’s 24 GHz sensors, but also to near- and mid-range applications such as front cross traffic alert and automated parking. The sensor could also find applications in the interior of the vehicle to sense gesture, an HMI enhancement. Hella, through its cooperation with InnoSenT, is developing radar sensors based on the chips from NXP. Slightly larger than a matchbox, Hella’s CompactRadar sensor measures just 45 cm$^3$. Production will begin in 2019 or 2020.

Operating at 77/79GHz, CompactRadar has higher resolution than 24 GHz radar. It will be used to support autonomous driving features, starting with automated parking, which requires a 360-degree view around the vehicle. Compared with standard ultrasonic sensors, CompactRadar has a larger field of view, better range and higher resolution. Given that CompactRadar will be more expensive than 24 GHz radar, at least initially, Hella expects the market for its 24 GHz sensors to stay strong, especially in the high-volume vehicle segment.

Eventually as the price of CompactRadar comes down, 77/79 GHz radar will begin to substitute for 24 GHz radar even in high-volume applications. Multiple “dumb” 77/79 GHz devices can share a single central computer, which would
lower the cost of each radar device. Plus, the transition from 24 GHz to 77/79 GHz will be facilitated by Hella’s modular approach; many of the components used in each sensor are identical. Nevertheless, CompactRadar is not expected to overtake demand for Hella’s 24 GHz radar before 2025. The competition for 77/79 GHz radar will come from Autoliv, Bosch, Continental and Delphi, among others.

Battery Sensors
Hella is the battery sensor market leader in Europe, number two in Asia, and will soon be number one in North America when shipments to one of the two largest carmakers there begin. Hella’s global market share is between 35% and 40%.

The sensors measure the current, voltage and temperature directly from the battery from which data the sensors’ algorithm supplies state of charge, state of health and state of function information. Hella can produce battery sensors in the U.S., Mexico, Europe and China at its own facilities, and in Korea with a joint-venture partner. Hella began producing battery sensors in 2001.

Hella’s Intelligent Battery Sensor

Battery sensors are required in vehicles with start-stop systems to ensure that sufficient cranking power is available to restart the engine. An important CO2-reduction feature, start-stop systems are becoming more common, according to the company. Hella is working on its next-generation battery sensor to make it more robust and cost optimized, and it is also adapting its technology to lithium ion batteries.
**12/48 Volt DC/DC Converters**

In anticipation of the demand for 48-volt sub-buses, Hella has developed a 12/48 volt DC/DC converter. According to Guido Schütte, director of energy management program management at Hella, carmakers such as Audi, Renault and Daimler will increasingly rely on 48-volt power to support CO2 reduction and as a means to more efficiently drive such power-hungry features as electric turbochargers and electrically actuated roll-stabilization systems. CO2 reduction features include electric boost, recuperation and start-stop systems.

**Hella’s Major Automotive Joint Ventures**

**Hella Behr Plastic Omnium**
Established: 1999
HBPO is a joint venture between Hella, Behr and Plastic Omnium specializing in the design, development, installation and logistics of completed front-end modules.

**Behr Hella Thermocontrol (BHTC)**
Established: 1999
Climate control and thermal management for the automotive industry

**HSL Electronics Corporation**
Established: 2000
The joint venture between Hella and Samlip (Korea) manufactures lighting electronics and products for energy management including the intelligent battery sensor and pedal sensor.

**Intedis**
Established: 2001
This joint venture formed by Hella and Leoni specializes in designing EE system architectures for vehicles.

**Beijing Samlip Automotive Lighting**
Established: 2002
Beijing Samlip Automotive Lighting produces headlamps, rear combination lamps and signal lights, primarily for Korean customers in China.

**Mando Hella Electronics**
Established: 2008
This joint venture between Hella and Mando pools both companies’ expertise in chassis systems and electronics as well as driver assistance systems.

**Changchun Hella Faway Automotive Lighting**
Established: 2012
The joint venture with Changchun Faway Automobile Components, a subsidiary of FAW, develops, manufactures and sells lighting systems and integrates electronics parts and control units in headlamps.

The Hansen Report on Automotive Electronics, October 2016
[www.hansenreport.com](http://www.hansenreport.com)
InnoSenT
Start of cooperation: 2013; Hella acquired 50% interest in radar supplier InnoSenT in 2012. The focus of the cooperation with InnoSenT is the development and production of radar sensors for Hella’s automotive applications. InnoSenT has expertise in 24 GHz radar as well as higher frequencies.

Beijing Hella BHAP Automotive Lighting
Established: 2014
Beijing Hella BHAP Automotive Lighting, the joint venture of Hella and Chinese automobile manufacturer BAIC, develops and produces headlamps and rear combination lamps for the Chinese market.

Hella’s Automotive Products

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<td>Intelligent battery sensors</td>
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<td>Voltage stabilizers</td>
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<td>Lithium ion battery management systems</td>
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<td>Fuel control modules</td>
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<td>Heating control modules</td>
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<td>Steering control modules (EPS ECUs) and sensors</td>
<td>Vacuum pumps</td>
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<td>Driver Assistance Systems (with 24 GHz (NB) radar technology)</td>
<td>Body actuators</td>
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<td>Lane change assist</td>
<td>Door/trunk applications</td>
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<td>Blind spot detection</td>
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<td>Pre-crash rear</td>
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The Hansen Report on Automotive Electronics, October 2016
www.hansenreport.com
Features and Functions Update for MY 2017

Infotainment and Connectivity
The industry average transaction price for a new light vehicle in the United States reached $34,372 in September 2016, according to Kelley Blue Book. That’s 2.5% higher than a year ago. Consumers seem willing to pay for all the new safety, convenience and entertainment features finding their way into an ever wider range of vehicles, even when it means adding pricey option packages to get them.

Unfortunately, problems with new infotainment features and functions continue to negatively affect vehicle reliability and consumer satisfaction. According to the J.D. Power 2016 Vehicle Dependability Study, the most problematic area of the vehicle is what it calls ACEN (audio, communications, entertainment and navigation), responsible for a 3% decline in overall dependability year over year. It is remarkable that Bluetooth pairing and voice recognition, both very mature technologies, still top the list of problems most often reported by vehicle owners.

Consumer Reports magazine saw similar complaints about voice recognition when it surveyed 58,000 vehicle owners about how satisfied they were with their car’s infotainment system. Complexity and non-intuitive menus were among the other complaints. In that survey, FCA’s Uconnect 8.4 infotainment system topped the satisfaction list, with 70% of users very satisfied with it. Ranking lowest in satisfaction was Cadillac Cue, which consumers reported being sluggish, confusing and having overly sensitive capacitive touch buttons. (Note: the average age of Consumer Reports print subscribers is 65, the average digital subscriber is 56.)

IHS Markit forecasts that connected vehicles will account for 55% of annual global new vehicle sales in 2020. In the developed markets, forecasts are closer to 100% of new light vehicle production. In the next four years carmakers need to step up their efforts to educate consumers about new vehicles’ features and how to use them, according to the 2016 Nielsen AutoTECHCAST Report released in August. Nielsen’s research revealed that one-third of consumers have never heard of connected cars and aren’t familiar with branded infotainment systems; others have concerns about how their data will be secured in a connected car.

General Motors, with two decades of experience in connecting cars through OnStar, was out front in offering compact models with technology features that appeal to millennials. Cruze buyers, for example, get a built-in 4G LTE wi-fi hotspot that can support up to seven mobile devices. An OnStar subscription and data plan are free for the first two years of ownership.

The Hansen Report on Automotive Electronics, October 2016
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FCA will offer 4G LTE for the first time in 2017 models of the Chrysler 300, Dodge Charger and Dodge Challenger equipped with the fourth generation Uconnect 8.4. Ford’s new Sync Connect feature, which debuts in the 2017 Escape, also uses an embedded 4G LTE modem for the first time. Previous generations of Sync required a brought-in smartphone for the connection. GM and Audi have offered onboard 4G modems since model year 2015.

The OnStar connection enables GM’s Proactive Alerts diagnostics service, which predicts when the battery, starter or fuel pump could fail, and the Teen Driver feature (more on that below). OnStar representatives might also call to personally wake up non-attentive drivers. GM’s Super Cruise Level 2 highway pilot feature, due from Cadillac in 2017, tracks the driver’s eye movements to determine if he is paying attention. The system issues audible and visual alerts to the driver if it detects he is not on task. If the alerts don’t work, an OnStar representative will be connected and communicate verbally.

Safety
Driver monitoring will become more widely used as more Level 3 and Level 4 piloted driving systems, which require the driver to be available to take over, are introduced. Some earlier driver alert systems such as those from Volvo in 2007 and Mercedes in 2009 monitored the vehicle, not the driver. Mercedes’ Attention Assist still uses vehicle sensors to detect changes in driver behavior. Lexus was one of the first with driver monitoring, introduced in 2005, using infrared cameras to track the driver’s head position and angle. More carmakers, including Audi, according to the Wall Street Journal, are expected to launch eye-tracking and facial recognition systems soon.

Despite the wider availability and affordability of advanced safety features in nearly all car segments, U.S. highway fatalities increased by 10.4% for the first half of 2016 compared with the first half of 2015, according to the Federal Highway Administration. Fatalities in 2015 increased 7.7% from 2014, not only because the stronger economy, lower unemployment and low gas prices led to more miles driven, but also because there were more accidents involving pedestrians, motorcycles and bicycles. Each day in the United States, more than eight people are killed and 1,161 injured in crashes that are reported to involve a distracted driver, according to the Centers for Disease Control and Prevention.

Teen drivers are among the worst offenders when it comes to distracted driving. While touchscreens and handheld devices will continue to take eyes off the road, many carmakers offer options for parents to at least remind and encourage their teens to be more aware behind the wheel. Chevrolet expanded its Teen Driver feature to nine more models for 2017, following its debut on the 2016 Malibu. The safety feature mutes the audio until seatbelts are buckled, and allows parents to set a maximum audio volume and maximum speed limit. It prevents disabling active safety features and reports miles driven, maximum speed, and the number of times safety features were activated.

The Hansen Report on Automotive Electronics, October 2016
www.hansenreport.com
### OEMs have been investing in technologies needed for autonomous driving and mobility solutions.

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
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<tbody>
<tr>
<td>Ford</td>
<td><strong>Velodyne</strong> Invested $75 million in the lidar sensor manufacturer</td>
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<td><strong>SAIPS</strong> Israeli image processing and deep learning developer acquired</td>
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<td><strong>Nirenberg Neuroscience</strong> Ford secured exclusive license to machine vision technology</td>
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<td><strong>Civil Maps</strong> Ford is one of 4 investors in the 3D mapping start-up</td>
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<td><strong>Chariot</strong> Crowd-sourced shuttle service acquired</td>
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<td><strong>General Motors</strong></td>
<td><strong>Lyft</strong> GM invested $500 million in the ride service. Lyft will test a fleet of autonomous Bolt EVs.</td>
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<td></td>
<td><strong>Cruise Automation</strong> Autonomous driving software developer acquired</td>
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<td><strong>Renault Nissan</strong></td>
<td><strong>Sylpheo</strong> Software development company acquired</td>
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<td><strong>Toyota</strong></td>
<td><strong>Jaybridge Robotics</strong> Hired all 16 employees from the MIT spin out</td>
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<td><strong>Audi, Daimler and BMW</strong></td>
<td><strong>HERE</strong> 3D maps, acquired from Nokia</td>
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<td><strong>BMW and Toyota</strong></td>
<td><strong>Nauto</strong> Licenses and equity in Nauto, specialist in data collecting and aggregating</td>
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<tr>
<td><strong>Volkswagen</strong></td>
<td><strong>Cymotive Technologies</strong> New VW unit established with three Israeli cybersecurity experts</td>
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<tr>
<td><strong>Volvo</strong></td>
<td><strong>Uber</strong> Partnered to develop autonomous vehicles.*</td>
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*Uber acquired Otto, a self-driving truck company created by a co-founder of Google’s self-driving program.