G M’s H elfrich on Powertrain C ontrols

Roadmap Points Toward Homogeneous Charge Compression Ignition

We took a trip out to the Milford Proving grounds recently to visit with Kent H elfrich, worldwide director of powertrain software engineering at General M otors. Powertrain engineering is particularly hot right now as carmakers worldwide re-double their efforts to tighten fuel consumption and emissions.

A good way to think about what’s next in engine controls and what requirements will be placed on electronics, says M r. H elfrich, is to consider the homogeneous charge compression ignition, or HCCI, engine. “Whether or not HCCI ends up being in every engine within the next 10 to 15 years, it represents the superset of a lot of the near-next-generation technologies.” Some of HCCI’s enabling technologies will indeed be viable enough to implement sooner.

M r. H elfrich explained HCCI this way: “HCCI is all about combustion efficiency. It would be like a diesel engine but somewhat lighter. The way we understand it right now, it would still have spark ignition, but we would get into the zone of compression ignition as soon as we possibly could. Transitioning between zones potentially gives you tremendous fuel economy without an expensive N O x aftertreatment system. While it is a fairly simple concept, the technology needed to implement it is very complex.” See the description of HCCI on page 3.

“A s a concept, HCCI has been around for decades, but the ability to control the entrance and exit from HCCI mode is only possible with very high-order computation and very fine control of the fuel mix. You can do it steady state, but you can’t get in and out with any sort of predictability.

“Just a few years ago the [HCCI] concept was considered very interesting, but only a laboratory exercise. The real challenge was moving from laboratory conditions to real-world driving conditions while maintaining smooth transitions into and out of the HCCI combustion mode. Now with advances in the technology of control, with fuel injection, with the computational capabilities, with digital signal processing and sensors, this is something that’s beginning to get real,” said M r. H elfrich.

One of the necessities of HCCI technology implementation is more accurate sensors. “We need to understand the exact state of the charge: the air coming in, the temperature, the humidity, the density. We have sensors that do that, but they turn to HCCI, page 3

Every April, C onsumer Reports magazine publishes its A nnual Auto Issue, which aims to give consumers all the information they need to know before buying a new or used car. O ne standard feature included each year is the Reliability Ratings for most models over the past six years. The ratings for each model year are based on the percentage of survey respondents who report serious problems in any of 16 trouble spots, compared with the average of all vehicles for that year.

Turn to Reliability, page 3

Volkswagen and Mercedes Lag

Reliability is a big factor in most people’s car buying decision. We took a close look at how the major carmakers compared with each other in electrical system, power equipment and audio system reliability. Reliability in the three areas we examined was consistently high for all carmakers, especially in power equipment. Asian carmakers claimed the top spot in all three categories, while G erman carmakers Volkswagen and M ercedes trailed the field in all three areas.

Problem Ratings for MY 2006 Vehicle Electrical Systems, by Carmaker

<table>
<thead>
<tr>
<th>Carmaker</th>
<th>0.5</th>
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<tbody>
<tr>
<td>Honda/Acura</td>
<td>0.9</td>
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<td>Toyota/Lexus</td>
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<td>Mazda</td>
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<td>Ford</td>
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<td>Nissan/Infiniti</td>
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<td>VW/Audi</td>
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<td>1.79</td>
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</tbody>
</table>

*Chrysler: 1.8 Mercedes: 2.53
Electrical includes starter, alternator, battery, horn, gauges, tire pressure monitor, wiper motor, wiring, lights.

GM’s H elfrich on Powertrain Controls
Radio Enhancements

Advances in digital signal processors, which process much of the audio input, are bringing further improvements in sound quality. A subset of these chips become more powerful, engineers are tweaking them to provide the best sound for a specific vehicle. "Some DSP systems are very sophisticated, with sound equalization and sound compensation for different configurations, even accounting for cloth or leather seats," said Ken Obuszewski, infotainment product manager at Freescale Semiconductor. He added that some high-end vehicles are beginning to add microphones to determine passengers' positions and adjust sound output to account for any changes.

The increasing power of these processors now makes it possible to reduce the number of DSP chips, which provides another nail in the coffin for stand-alone amplifier systems. "Post processing and other functions that have been in the external amp are in some cases migrating into the head unit," said Ken Nevard, strategic marketing manager for Analog Devices' Analog Component Group. This post-processing includes equalization and other jobs.

However, as more functions move into the radio head unit along with navigation, telematics, M3 inputs and others, electromagnetic coupling isolation becomes an increasingly important part of design. "There are more sources of noise," said Jeff M arrah, Delphi's principal technical fellow for R.F. Mr. M arrah believes that although eliminating crosstalk is challenging, it's usually not a roadblock.

He also noted that while chip speeds are improving, many of the advances, for example better reception quality, are now happening in software. "We're doing things in our DSP algorithms to enhance reception performance," Mr. M arrah said.

The rise in DSP capabilities also makes it possible to replace conventional hardware-based tuner devices with software-defined radio (SDR). This technique, developed for military applications where many different types of radios are used, makes it much simpler for radio designers to bring in signals from multiple sources. That's important as inputs explode beyond basic AM and FM. In the U.S., there are two satellite sources and the emerging HD Radio, while DAB and DRM are the digital broadcasting schemes in Europe. "Software defined radio is very useful. Radios can be tailored for the requirements in different locations," A D I's M r. W aurin said.

SDR is making its way into vehicles. "Delphi is already shipping our second generation of software defined radios, and we're architecting the third generation," Mr. M arrah said.

The ability to handle many inputs is being addressed in other ways. Looking forward, product designers are exploring ways to let every passenger listen to a different radio station. That can be handled by employing different architectures and components. For example, NXP Semiconductors recently detailed a sigma delta converter it's developing. This new type of analog to digital converter has the bandwidth to digitize all the channels coming into a radio. Production of the device is still a couple of years off, but the Philips spin-off has high hopes. "Every communications standard we see in daily life—A M, FM, Wi-Fi, cellular—can be served with sigma delta analog to digital converters," said Leo W armerdam, senior research director at NXP.

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HCCI...

need to be more accurate, cheaper, longer lived and more robust to variations,” explained Mr. Helfrich. “We need to know everything about the combustion event: how much air is inducted, how much fuel is injected, how it mixes and if the walls are wet inside the chamber.”

Not yet widely applied in automotive applications, real-time pressure sensors capable of measuring inside the combustion cylinders are especially crucial. “I can imagine having a sort of DSP function separate from the main processor that calculates combustion parameters such as the location of peak pressure in each cylinder. Then you could precisely control the amount and timing of fuel being injected and thus control stratification of the charge mixture inside the cylinder head as its being compressed and then as it combus. You would then know when you are at the edge of transitioning from spark ignition to compression ignition and be able to gracefully move back into spark ignition,” noted Mr. Helfrich.

At most, one pressure sensor would be required per cylinder. But, said Mr. Helfrich, “You may be able to get by with one pressure sensor in each bank, or in a 4-cylinder engine, one for the whole block.” Even without HCCI engines, combustion pressure sensors would be a boon to designers of spark ignition direct injection engines.

“Aiso are the fuel injectors and fuel rail. “You’re injecting very precise amounts of fuel, essentially shaping the fuel cloud and the combustion event,” he said.

Software Tool Requirements

With hundreds of software development projects underway around the world, Mr. Helfrich is in a great position to suggest ways in which tool suppliers can help:

- Tools that automatically generate code based on models need to be capable of writing code that is small, efficient and tight. “I am very concerned with some of the tools coming out as we go from handcrafted software to auto code generation from models,” said Mr. Helfrich.
- GM has people jointly working on software at multiple locations, in Europe, North America and Asia. A ny tool that GM uses needs to be supported at those multiple locations and they need to be the same versions. “When you revise a tool for one market you have to have a migration path for the entire globe.”
- A t the auto industry progresses toward systems that steer and brake autonomously and toward hybrid powertrains, hardware and software development tools will need to comprehend safety-critical engineering. Mr. Helfrich: “We have to build into these systems safety-critical protection algorithms, perhaps dual calculation paths, interface storage redundancy, rate limits on actuators and so forth. A nd the hardware will evolve too. We may use dual core processors or smaller processors off to the side doing redundant calculations, all at a very reasonable cost.”

Homogeneous Charge Compression Ignition (HCCI)

What is it?

A subject of intense research in Japan, Europe and the United States for nearly two decades, HCCI engines incorporate the best features of both spark ignition direct-injection (SIDI) engine and compression-ignition direct-injection (CIDI) or diesel engines.

As in an SI engine, the charge (air-fuel mixture) is well mixed, which minimizes particulate emissions, and as in a CIDI engine, it is compression ignited and has no throttling losses. However, unlike either of these conventional engines, combustion occurs simultaneously throughout the cylinder volume rather than in a flame front.

Potential Benefits

- Highly efficient
- Produces ultra-low oxides of nitrogen (NOx)
- Minimizes particulate emissions
- Operates on gasoline, diesel fuel and most alternative fuels
- Lower cost than CIDI engines due to lower pressure fuel injection
- Lower cost emission control
- Applicable to both light- and heavy-duty engines

Source: U.S. Department of Energy

Reliability...

Consumer Reports explains that if a model scored relatively badly in a particular area, for example, electrical, it doesn’t necessarily mean that the model’s electrical system is unreliable, only that it had more electrical problems than the average model. The average problem rate in our example of electrical systems was quite low.

To determine our rankings, we assign a numerical value to Consumer Reports’ relative reliability scores, which the magazine illustrates with red and black filled or partially filled circles. We weight that assigned value with U.S. sales data for each model published in a national news or provided by the carmakers.

This is the first year Consumer Reports segregated audio in its own category. Included are the radio, CD player or changer, cassette player, satellite radio, navigation and entertainment systems.

<table>
<thead>
<tr>
<th>Problem Ratings for MY 2006 Vehicle Audio Systems, by Carmaker</th>
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<td><strong>Honda/Acura</strong></td>
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<td><strong>DCX</strong>*</td>
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<td><strong>Ford</strong></td>
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<td><strong>GH</strong></td>
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<td><strong>Nissan/Infiniti</strong></td>
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<td><strong>BMW</strong></td>
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<td><strong>VR/Audi</strong></td>
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</table>

*Chrysler: 1.44  Mercedes: 3.56

Audio includes radios, CD players and changers, cassette players, satellite radio, navigation and entertainment systems.

Problem Ratings for MY 2006 Vehicle Power Equipment, by Carmaker

| **Carmaker** | **Chrysler: 1.38** | **Mercedes: 2.11** |
|---------------------------------------------------------------|
| **Mazda** | 0.9 | 0.9 |
| **Toyota/Lexus** | 1.04 | 1.10 |
| **Honda/Acura** | 1.05 | 1.18 |
| **Hyundai/Kia** | 1.18 | 1.45 |
| **DCX*** | 1.46 | 1.47 |
| **Ford** | 1.47 | 1.55 |
| **GH** | 1.55 | 1.80 |
| **Nissan/Infiniti** | 1.80 | 1.96 |
| **BMW** | 1.96 | 1.96 |
| **VR/Audi** | 2.00 | 2.76 |

*Chrysler: 1.38  Mercedes: 2.11

Power equipment includes power windows, locks, mirrors, seat adjustors, sunroof, convertible top, sliding doors or lift gates, keys less entry, cruise control, heated and cooled seats, backup sensors and cameras.

Continued from page 1
Bosch Group Background

Following a brief stint working for Thomas Edison in New York and another working for the Siemens Brothers in London, 25-year-old Robert Bosch established his Workshop for Precision Mechanics and Electrical Engineering in Stuttgart in 1886, the same year Carl Benz received a patent for his four-stroke gasoline engine vehicle. By 1900, Bosch was manufacturing ignition systems for cars and expanded into automotive lighting in 1913.

Throughout the first half of the twentieth century Bosch developed increasingly sophisticated fuel injection systems for diesel and gasoline. By 1979 the company had integrated ignition and gasoline injection into complete electronic engine management systems. Further technical advances and strategic acquisitions enabled advanced safety systems including antilock braking and ESP, Bosch’s electronic stability program, as well as navigation and driver assistance products.

In 2006, Bosch was number one on Automotive News’ list of top global OEM parts suppliers, based on 2005 sales. Sales in the company’s Automotive Technology business sector, which accounts for 62% of total sales, grew by 3.5% in 2006, to more than €27 billion, despite a 3% to 4% drop in average selling prices. More than half of automotive sales come from diesel and gasoline engine-management parts. The remainder of Bosch Group sales comes from the Industrial Technology and Consumer Goods and Building Technology business sectors. The Bosch Group comprises approximately 300 consolidated companies in more than 50 countries.

A grid to the company, it was the founder's wish that the company “should remain at all times financially independent, autonomous and able to take appropriate actions,” that is, to make long term investments that will ensure the company’s financial health. In 2006, the Bosch Group invested €3.3 billion in research and development, most of it automotive related. In 2006, Bosch filed 3,056 patent applications.

The majority owner, with 92% of equity (but no voting rights), is the nonprofit charitable foundation Robert Bosch Stiftung. The remaining 8% of shares are held by the Bosch family, which controls 7% of voting rights. Since 1964 the foundation has channeled more than €730 million to science, healthcare, international relations and educational projects.

Ninety-three percent of voting rights are held by Robert Bosch Industriegriechhund KG, an industrial trust. A Board of Management is responsible for day-to-day operations and decision making. A private company Bosch has only limited access to equity markets for funding, so it must fund its 6% to 8% targeted annual sales growth entirely out of its own cash flow. “So we set ourselves a profit target of 7% to 8% before taxes,” noted Bernd Bohr, member of the Bosch board of management. “In the past organic growth has been 5% to 6% per year and external growth [acquisitions] has been 2% to 3% per year.”
Dr. Bohr has been on the board of management of Robert Bosch GmbH since 1999 and chairman of the Automotive Technology Group since mid-2003. He also has corporate responsibility for quality and divisional responsibility for chassis, gasoline and diesel systems, steering systems and regional responsibility for India. He is doctorate in engineering from the University of Aachen, Germany.

While acquiring Siemens VDO is unlikely, given much overlap there is in the two companies’ automotive product lines, Bosch has made some fairly substantial acquisitions in the past decade including A llied Signal’s brake business in 1996, the majority of Zexel, a Japanese maker of diesel fuel injection pumps and nozzles, in 1999, Rexroth in 2001 and the majority of Pacifica Group in 2007.

Most of the funds that Bosch devotes to basic research are aimed at reducing emissions and fuel consumption as well as improving safety. The EU has a goal to dramatically reduce fatalities to no more than 25,000 per year by 2010, half as many fatalities as in 2000. Still, safety is a global concern: “In India, there are about 80,000 deaths per year, with a vehicle fleet of just 9 million vehicles, compared with Europe with a fleet of 200 million vehicles. So much of our research is toward advancing safety,” said Dr. Bohr.

**Competence in Engine Control Systems**

When it comes to engine control systems Bosch is number one in the world and that dominance will serve the company well—particularly now as carmakers worldwide respond to the growing pressure to develop vehicles that pollute less and go farther on a tank of gas or diesel fuel. Bosch’s expertise is especially valuable given the real concerns about global warming and the almost irrefutable evidence that carbon dioxide exhausted from vehicles is responsible for nearly one-fifth of CO₂ emissions, the main contributor to global warming. “CO₂ will remain one of the megatopics in the next few years, so reducing consumption is a huge area,” Dr. Bohr noted.

Pressure to build more fuel-efficient vehicles is ratcheting up even in the United States. In early April of this year the U.S. Supreme Court ruled that carbon dioxide and other greenhouse gases are indeed air pollutants that can be regulated by the Environmental Protection Agency, which thus far has done little to curb CO₂ emissions. The ruling will give a huge boost to lawmakers working on legislation that limits emissions. According to the New York Times, at least 300 bills have been filed in 40 states that address heat-trapping gases and climate change in some form.

**Clean Diesel**

For many consumers, cars powered by diesel engines are a promising option. They are powerful and therefore fun to drive. Since diesel engines provide 30% better fuel economy than gasoline engines, they produce approximately 25% less CO₂. Already the world’s number-one supplier of diesel fuel-injection systems, Bosch has undergone a significant number of engineering projects for diesel common rail systems: 50 in China and 30 in India alone, according to a January 2007 press briefing by Franz Fehrenbach, chairman of Bosch’s board of management.

“There are a lot of new projects in India. For instance, Maruti Suzuki is building a diesel plant that is now ramping up. And Tata is introducing new diesels, as is Mahindra and Mahindra,” said Dr. Bohr. He estimated that diesels could account for a 50% share of the passenger car market in India.

“In China, while diesel penetration in passenger vehicles is now close to zero, the Chinese government has made it very clear in a five-year plan that they will support low-consumption powertrains for the mass motorization of China,” said Dr. Bohr. “They have explicitly named hybrids and clean diesels for these.”

Even the United States is fertile ground for diesel development. Currently, according to Dr. Bohr, 6% to 7% of light vehicles in the U.S. use diesel engines, a continued on following page
Bosch Group

Global Investments

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Location</th>
<th>Investment Period</th>
<th>Investment</th>
<th>Major Projects</th>
<th>Ownership</th>
<th>Employees</th>
<th>Products or Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Bosch Corporation* (Tokyo)</td>
<td>Sales 2005: ¥309,979 million</td>
<td></td>
<td>11.34% of Akebono shares</td>
<td>Bosch owns 58.80%</td>
<td>7,700</td>
<td>Products: fuel injectors, diesel engines, electronic control units (ECUs) for airbag systems, sensors, and more.</td>
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<tr>
<td></td>
<td>Nippon Injector Corporation (Odawara)</td>
<td>Sales 2005: ¥8,635 million</td>
<td></td>
<td></td>
<td>Bosch ownership: 50%</td>
<td>264</td>
<td>Products: fuel injectors, diesel injectors.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Akebono Brake Industry</td>
<td>Bosch owns 11.34% of Akebono shares; Toyota holds the largest share</td>
<td></td>
<td></td>
<td></td>
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<td>Diesel systems, smart brakes, and electronics.</td>
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<td></td>
<td>Denso</td>
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<td></td>
<td>Products: common-rail diesel system, gasoline systems.</td>
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<tr>
<td></td>
<td>Bosch Corporation</td>
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<td>Bosch Braking Systems, Bosch Electronics Corp. and Bosch KK.</td>
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<td></td>
<td>Denso</td>
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<td></td>
<td>Bosch Corporation was formed between 2002 and 2005 through the merging of Bosch Automotive Systems, Bosch Braking Systems, Bosch Electronics Corp. and Bosch KK.</td>
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<tr>
<td>India</td>
<td>Total investment: €325 million from 2005 to 2008</td>
<td>Major project: Production of common-rail diesel systems</td>
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<tr>
<td>Korea</td>
<td>Total investment: €100 million from 2005 to 2010</td>
<td>Major projects: Production of common-rail diesel systems; expansion of the technical center in Yongin</td>
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<td>Korea</td>
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<td>Bosch ownership: 58.80%</td>
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percentage that he expects will grow to 15% by 2015. “We are working on diesel projects for the U.S. with all the major American and European OEMs as well as some Japanese OEMs,” he said. In Europe, diesel’s share of the passenger-vehicle market is slightly above 50%.

Sales of diesel-engine-powered vehicles will be limited in the United States, where expensive exhaust cleaning systems are required to meet tough federal and state limits on nitrous oxide and particulate emissions. According to Dr. Bohr, in Europe a typical 2-liter diesel engine costs roughly €1,500, compared with about €1,000 for a gasoline engine. But in the United States, a typical 6- or 8-cylinder diesel engine that is Tier 2/Bin 5 compliant (meaning it can be sold in all 50 states) will cost approximately $2,000 more than a comparable gasoline engine.

By the middle of 2008, a new Bosch Denoxtronic system for passenger vehicles will be available to help diesel engine producers meet the most rigid clean-diesel standards. The system automatically meters into the exhaust stream precise amounts of aqueous urea solution that converts nitrous oxides into water vapor (in an SCR catalyst).

Other advancements from Bosch serve the demand for clean diesel engines. For example, the company’s third-generation common rail system stores fuel in the accumulator (rail) at 1,800 bar. The high pressure results in more precise control of the combustion process. Fuel metering precision is also aided by Bosch’s piezo injectors, which turn fuel delivery off or on five-times faster than solenoid-actuated fuel injectors.

Despite the additional cost of clean diesel technology, numerous carmakers, including BMW, Mercedes, Chrysler, Volkswagen, Audi, Honda, and possibly Hyundai will introduce new diesel-powered vehicles to the U.S. market within the next few years.

Gasoline Direct Injection

Reducing carbon dioxide emissions will also invigorate demand for state of the art gasoline injection systems from Bosch. The European Commission recently proposed rules for carmakers to reduce carbon dioxide emissions from new cars to an average of 130 grams per kilometer by 2012. Thus far, efforts aimed at reducing CO₂ emissions to 140 grams per kilometer by 2008 have been voluntary.

“In Europe especially we see gasoline direct injection in conjunction with turbocharging and slightly downsized engines coming on quite significantly,” noted Dr. Bohr. “We are seeing 150- to 200-bar injection pressures compared with fuel injection of 6 to 8 bar. Bosch systems include the high-pressure pump and injection valves, sensors, electronics control unit and engine control strategy. “We don’t just do the injection system, we do the combustion as well; so we can do a lot of consulting to those OEMs who may not have the resources or expertise in that area,” he added.

Flex Fuel

A nother opportunity for Bosch to profit from leading-edge fuel-management technology comes from the commitment made by top executives at GM, Ford and Chrysler to increase their production of E85 vehicles to about 2 million units a year by 2010. (E85 is fuel made from a blend of 85% ethanol and 15% gasoline.)

The Detroit carmakers were responding to a proposal by President Bush to mandate a five-fold increase in the production of ethanol and other alternative fuels over the next decade in order to reduce U.S. dependence on foreign oil.

“We have a lot of experience developing flex-fuel vehicles in Brazil, experience we hope to leverage in other markets, especially in the States,” Dr. Bohr pointed out. “Ethanol is quite an aggressive fluid, so fuel system components must have special corrosion protection. As a result, quite a bit of know-how is necessary for the algorithm development, because a driver may put gasoline in the tank one day and E85 the next day. So the system needs to determine from the various sensor signals how much ethanol is in the tank, and it must be able to adjust engine management parameters accordingly.”

Flex-fuel vehicles require extra components that cost between $50 and $100 per engine. Bosch plans to begin volume production of flex-fuel engine management systems in the U.S. in the 2009 or 2010 timeframe.

Active Safety

Electronics stability control was first developed by Bosch and introduced on the Mercedes S-class in 1995 (under the name Electronic Stability Program), and sales of the life-saving safety feature keep...
on growing. In the United States alone from 2006 to 2010 sales of Bosch ESP will triple, from 900,000 to nearly three million units annually. In April 2007 the U.S. Department of Transportation issued its final ruling requiring the feature to be installed on every new passenger vehicle sold in the 2012 model year, with phase-in starting in model year 2009. Regardless of the mandate, Ford had already said it will make ESC standard on all new vehicles by the end of 2009 and GM will do the same by 2010. NHTSA estimates that ESC will save between 5,600 and 9,600 lives annually when fully implemented, and calls it the greatest safety innovation since the airbag.

Bosch expects demand for ESP to grow in Europe as well, from around 42% penetration of new vehicles today, despite the fact that the feature has not yet been mandated there. “We see growth in Europe,” said Dr. Bohr. “So many smaller cars are not yet equipped. And the safety benefits are so convincing.” The European Commission has sponsored a campaign in the first half of 2007 in Europe promoting the safety benefits of ESP.

While it has been referred to as a convenience feature, and a rather expensive one at that, Bosch expects sales of its adaptive cruise control (A CC) systems to pick up as A CC is cross-linked with ESP, A BS and hydraulic brake-assist systems and complemented by a video camera—thereby contributing to safety.

Such systems will soon be capable of recognizing pedestrians and other obstacles and will initiate braking automatically. Last year the Audi Q7 included a Bosch system that briefly applies the brakes to draw the driver’s attention to the road ahead. By 2009, Bosch systems will be capable of more forceful automatic braking, up to 60% to 70% of full braking. Reducing the energy of the impact reduces the severity of an accident.

Why Bosch?

What distinguishes Bosch from its competitors? Why do its customers buy from Bosch rather than from the competition? First and foremost, according to Dr. Bohr, Bosch means innovation. “If you look at our core product domains—powertrain, safety and sensors—we are quite often the first with new technology. And even when we are second, we are close behind the leader.

“Second, when a customer says they are setting up a new production site somewhere, there is a good chance that Bosch is already there. Compared to our competitors, Bosch’s footprint is the most global. We have our home market in Europe, but we also have a strong footprint in the U.S. and especially in Asia. We were very early in China, and we have been in India, where we now have 15,000 people, since 1954. You can even work with Bosch in South Africa, in Australia and in Russia.

“Third is dependability. We are financially very stable and we have been in business over a hundred years. We are one of the sure bets in this very dynamic supplier environment.

“A nd finally, we are very strong technologically. We invest nearly 10% of sales in R & D, more than any of our large competitors.”

Bosch Automotive Technology

2006 Sales: €27.2 billion ($36.3 billion)
Change from 2005: up 3.5%

Outlook for 2007: Bosch intends to grow sales through increased demand for its products globally, especially diesel injection in China and India and increased penetration of electronic stability control in the United States.

According to Bosch, selling prices for its products fell an average of 3% to 4%, while raw material prices rose considerably. Lower production volumes at U.S. carmakers led to a drop in capacity utilization at Bosch’s North American plants.

Please see the Company Profile of Bosch, page 4.

Brose Group

2006 Sales: €2,340 million ($3,124 million)
Change from 2005: up 6%

Europe accounted for 79% of 2006 sales. The privately-held maker of window regulators, door systems, seat adjusters and door latches employs more than 9,100 people in 20 countries. In 2006, Brose opened a third production facility in China.

Brose develops most of its own electronic control units and manufactures some electronics in-house. A new Brose product was introduced on the BMW 3 series coupe in the fall of 2006. The device Brose calls a seat belt carrier uses a small motor to deliver the seat belt latch from its retracted position behind the front occupant’s shoulder to a convenient, reachable position. The seat belt carrier has an anti-trap function and is linked with the occupant detection system.

Continental Automotive Systems

2006 Sales: €5,994.4 million ($7,469.6 million)
Change from 2005: up 14.6%
2006 EBIT: €532.2 million ($710.6 million), compared with €570.1 million ($761.2 million) in 2005

In July 2006 Continental bought Motorola’s automotive electronics business, which included controls, sensors, interior electronics and telematics, notably including GM’s OnStar business. The one-billion dollar acquisition helped boost Continental’s sales in North America by 38.5%.

Continental expects the proliferation of eCall systems will sharply increase its telematics sales in Europe in the coming years. Growth is also expected through the application of telematics technology to car-to-car communications systems aimed at preventing accidents, though that application will take many years to develop.

In January 2007, Continental and Microsoft formed a strategic alliance through which they will integrate Windows Automotive software into consumer entertainment systems, beginning with the Ford Sync platform.

Continental also acquired the automotive sensor business of VTI Technologies Oy of Finland, in October 2006. The company makes low-g acceleration and inclination sensors.

In the summer of 2006, Continental met with private equity investors (reportedly Bain Capital) interested in a buyout of the company, but the discussions were officially terminated in September, according to Continental. Continental has expressed interest in acquiring some or all of Siemens VDO, which may be spun off later this year.

Gentex

2006 Net Sales: $572.3 million
Change from 2005: up 6.7%
2006 Net Profit: $108.8 million, or 19% of sales, compared with 20.4% of sales in 2005

A automotive products accounted for 96% of total Gentex sales. Gentex, the world’s leading supplier of electrochromic auto-dimming mirrors, sees room for growth in its primary product area. According to the company, at the end of 2006 global penetration of interior automatic dimming mirrors had reached only 18%; exterior auto-dimming mirrors, 6%.

Unit shipments of mirrors increased 7% over the prior year, primarily due to increased business with General Motors and increased penetration on European and Asian vehicles. Gentex’s largest customers are GM, accounting for 22% of sales, DaimlerChrysler, 15% of sales, Toyota, 13% and BMW, 12%.

During 2006 Gentex announced development programs with some automakers for its Rear Camera Display mirror, which features an LCD built into the rearview mirror. The LCD is illuminated when the car is put in reverse and displays the image from a rear mounted video camera.

Other innovative electronics features Gentex has integrated with its mirrors include OnStar push-buttons, JCI’s Homelink, tire pressure monitors, Gentex’s SmartBeam headlamp controller and automotive grade microphones.

Domestic Japanese Shipments* of Automotive Consumer Electronics Equipment, 2006

<table>
<thead>
<tr>
<th>Product</th>
<th>Units 2005</th>
<th>Change from 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car Navigation</td>
<td>4,014</td>
<td>+3.6%</td>
</tr>
<tr>
<td>DVD ROM</td>
<td>1,938</td>
<td>-22.0%</td>
</tr>
<tr>
<td>HDD and other**</td>
<td>2,047</td>
<td>+55.0%</td>
</tr>
<tr>
<td>Color TV</td>
<td>1,011</td>
<td>-15.2%</td>
</tr>
<tr>
<td>DVD players</td>
<td>253</td>
<td>+18.1%</td>
</tr>
<tr>
<td>Cassette stereos</td>
<td>582</td>
<td>-18.0%</td>
</tr>
<tr>
<td>CD players</td>
<td>6,632</td>
<td>-0.1%</td>
</tr>
<tr>
<td>Car radios</td>
<td>708</td>
<td>-9.1%</td>
</tr>
</tbody>
</table>

*OEM and aftermarket
**Including portable devices

Source: JEITA

Intelligent Vehicle Safety Conference Debuts May 22

Telematics Update, which organizes successful conferences around the world on telematics and navigation, is venturing into the hot automotive safety arena. Intelligent Vehicle Safety - Detroit, a one-day conference and exhibition, will convene on May 22, 2007 at the Rock Financial Showplace in Novi, Michigan. It will be co-located with Telematics Detroit, a two-day conference that starts on the same day.

Among the many presentations and panels is a session on driver distraction, safety and the human machine interface, moderated by Paul Hansen. The panel will feature executives from Microsoft, Johnson Controls and Visteon, among others. So far, 50 telematics and safety exhibitors have registered for the conference; about 70 are expected.

For more information, please visit www.telematicsupdate.com.