Power Line Communications
Market Remains Modest

The idea to use the 14-volt power line as a data highway has been around for several years. Power lines are available throughout the vehicle, so why not use those existing lines for signals as well? **Yamar Electronics**, a seven-person firm based in Tel Aviv, Israel, and Valeo have each developed technology that uses the vehicle's power cables to communicate with electronics components. **Yazaki** has been studying and experimenting with power line communications (PLC), using some Yamar technology as a starting point. But despite the continued interest and recent development activity, PLC is stuck in the slow lane.

Yamar Electronics has been promoting its patented DC-Bus version of PLC since the mid-1990s, well before Valeo began exploring the application. And while 10 Yamar customers are currently investigating PLC applications, for example, in sliding doors, climate control, back lighting and in truck-trailer applications, none are soon headed for the sort of high-volume OEM production indicative of a major trend toward the technology. Yamar offers a range of power line modem/transceivers, each designed for different protocols: CAN (10 kbps or 250 kbps), LIN (57.6 kbps) and SPI/UART (500 kbps).

Valeo began its work on low-speed (20 kbps) PLC in 2001, targeting 2006 for its initial production applications, but no low-speed automotive applications have materialized. A's with most new technology, the initial problem is cost; at least that is the case with using PLC as a possible replacement for wired LIN networks. High volumes make LIN a cost-effective solution. A according to Valeo, while the transceivers needed at each node in the PLC bus are too expensive at low vol-

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**HMI on the Front Burner**

XML Standard Hits Snag

At carmakers around the world designers are working on human machine interfaces (HMI) that must not only define their vehicles and set them apart from the competition, but also provide safe interfaces to a proliferation of embedded features, as well as numerous portable devices that drivers operate in their vehicles.

"There is a kind of tipping point on the side of HMI development for the auto companies in that they are putting more and more displays in everything—the center stack, the instrument cluster, rear seat entertainment. And this has created somewhat of a bottleneck, because HMI development is a pretty complex, compute-intensive, graphics-intensive problem," said M. Jurian, CEO of **Altia**, a software company that provides user interface design and development tools. At the time of our conversation, M. Jurian was in Sweden visiting with Saab and Volvo.

"The problem is that carmakers are typically not so good at creating this 'wow factor,' this engaging, branded, differentiating user interface. They don't have a lot of programmers," explained M. Jurian. "The first-tier suppliers have programmers, but they are often control system programmers, not user interface developers and programmers. A a result, development is often late or they design something that is sub-par.

"The other problem for carmakers is they are competing with the consumer electronics world. Consumers have gotten used to something on the level of the iPod and video games. animated graphics and aesthetically rich user interfaces. But carmakers don't have that core competency," said M. Jurian.

Part of what's driving this explosion in HMI is, said M. Jurian is the availability of inexpensive hardware. "The consumer electronics, iPods and PDAs are manufactured by the millions. So now you can get Quarter VGA screens [video graphics arrays with 320 x 240 pixels] or even widescreen VGA's from Fujitsu or Sharp at prices that make sense for carmakers.

"The other breakthrough is the emergence of FPGAs [field programmable gate arrays]. For example, **Altera** recently released chips in the $5 per chip range that can do full-motion video and animated graphics," he said. Invented by **Xilinx**, FPGAs are logic devices that can be quickly programmed by the customer to perform specific functions.

Peter A bowd, formerly a director of embedded software development at **Visteon**, has witnessed some of the challenges that carmakers and suppliers face as they try to create cohesive and nondistracting user interfaces. "The consumer electronics would like to take charge of the entire HMI—the interfaces to climate control, cluster and radio. But historically it has been a disparate set of suppliers that has the skill base and technical capability to implement those individual user interfaces. The challenge for the OEM's is to specify the whole coordinated system and still source it individually to their traditional suppliers," he said. "A nd if I am a supplier of one of the components of an instrument panel, how do I model an HMl that might be shared with two or three other devices, with user inputs that may be in multiple modalities, from switch inputs or from speech?"

The problem is compounded by the expectation that more portable devices of varying brands and unknown capability will be brought to market. "One could try to have the driver take control by means of a common input modality, but that is very difficult," M. Jurian observed. "In my opinion, Visteon is several years ahead of the industry in its ability to build model-based HMI and automatically generate code."
FlexRay Moving Slowly Toward Volume Production

I have just returned from Fachkongress Elektronik, the important, high-level meeting of the German automotive electronics brotherhood that takes place each year in beautiful Ludwigsburg. During the conference I was able to quickly survey top engineers from the carmakers and key managers from component, tool and software suppliers about the status of FlexRay, the safety-critical, high-bandwidth alternative to CAN for vehicle networks.

BMW pioneered FlexRay, together with Mercedes, NXP and Freescale, and was the first to put it in a production vehicle. In 2006 BMW used FlexRay in a damper control system on the X5 sport activity vehicle. Having climbed the learning curve with the X5, BMW will exploit the network more fully in the new 7 Series, due in 2008. “We will use FlexRay in the 7 Series [to implement] driving dynamics features: an improved stability system, improved steering system and improved ride and handling systems,” offered Walter Kuffner, director engineers from the carmakers and key managers on FlexRay. “For electronics driving dynamics, BMW Group. “For the next cars, beyond 2010, we are thinking about sensor fusion on FlexRay.” Sensor fusion combines inputs from multiple sensors, for example, from camera, radar, lidar and/or ultrasonic sensors.

Audi has also committed to using FlexRay in production, on the next A8. Depending on options, from six to ten nodes in one channel will be deployed in chassis control and driver-assistance systems. According to reports, the next A8 is due in mid-2009 or later.

Volkswagen might follow the A8 two years later with a FlexRay implementation, if it gets the green light to bring a new Phaeton luxury model to market. The vehicle platform on which the Phaeton is built will be shared with Audi.

Mercedes says it will deploy FlexRay, but not until the new S-Class comes out, which won’t be for another five years. “We are happy not playing the front runner,” wrote Stephan Wolfsried, Mercedes’ top electrical engineer, in an email to The Hansen Report. “We did that with CAN and MOST, and our experiences have not been completely positive in terms of maturity and initial challenges.”

In Ludwigsburg, Porsche’s top EE, Uwe Michael, told us that while Porsche is “working on specific issues to be prepared on FlexRay ... we do not plan to bring it out soon. When FlexRay first came out, the killer applications were in the dynamics of the car, chassis things. A t the moment the killer application seems to be just high-volume data for cameras. We are waiting for the right killer application.”

Different Bit Rates for Japanese Transceivers

While no Japanese carmaker has yet gone on record with plans to put FlexRay into production, JAPA R (Japan A Automotive Software Platform and A architecture), the Japanese consortium founded in 2004, has been working with the FlexRay specification in anticipation of Japanese carmakers eventually using it.

The Japanese, however, will likely deploy FlexRay at lower bit rates than the Germans. A according to an email from Toshimi Abo, a top Niss an electrical engineer who helped found the consortium, “JAPA R is trying to define two applications based on the original 10 M bps FlexRay application. One is 5 M bps/6 nodes targeting safety-related systems, and the other is 2.5 M bps/22 nodes for CAN replacement.”

Another company with FlexRay development expertise is TTTech Automotive, the Austrian company whose mission is to use its vast experience with time-triggered technology to support the FlexRay standard. With nearly 25% of the company owned by Audi, TTTech Automotive is a member of the A U T O S A R and has a representative in Japan who works with JAPA R. “The X5 has a point-to-point connection for the FlexRay system. The 7-Series and the A 8 will have networks. That is a big difference,” noted M arkus Plankensteiner, director of marketing for TTTech Automotive. “With flexRay we have a complete tool chain, including development and testing hardware, covering almost the entire development process described in the V-model.”

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XML Standard for HMI in Doubt

Seven months ago we reported that audi, BMW, DaimlerChrysler and Porsche engineers agreed to accept version 1.0 of a new Volkswagen-developed standard that uses XML (the extensible markup language used on the web) to specify the HMI requirements of audio and navigation systems. But, according to Stephan Wolfsried, DaimlerChrysler’s top electrical engineer, Mercedes will not use XML as a standard. Citing “bad experiences in setting standards,” he said that some of his suppliers are not able to follow such a requirement off the shelf. One supplier described its experience with the standard as “horrible,” adding, “You couldn’t take the XML and generate code from it. You had to optimize it first.”

Audi’s Mike Juran suggested, “There is nothing in it for the OEM’s to make things standard, so they all have a level playing field.” He believes that any HMI standardization will come from a tool vendor or a supplier teaming with an OEM and creating a “killer” infotainment system or instrument cluster interface. Their success will inspire others to follow.

Still, according to M. Juran, using XML to specify HMI does have more immediate practical value—as a way to transfer data from one tool in the process to the next. “For example, the OEM might draw their concept of an HMI in a tool like Photoshop or Illustrator. It would be nice if you could extract that as a standard format that other tools can read, and then maybe a code generator could turn that description into deployable code. XML is a really good way to pass data between disciplines, from art, to systems engineering, to software development.”

M. Juran explained Audi’s role in the process: “Our purpose in life is to help the OEM’s prototype these HMI’s and get a feel for how they are actually going to operate. Then we help the suppliers turn those ideas into deployable code.” In business for 15 years, Audi’s largest customer is GM, followed by Chrysler. The company also serves Ford, BMW, Audi, Jaguar, Renault and Fiat.

A another company supporting automotive HMI development with tools is Elektrobit (EB). Elektrobit has been working closely with Volkswagen and Audi on HMI specifications. Thomas Fleischmann, product manager of HMI tooling at EB, agrees that an XML standard would be useful in bridging the gap between OEM’s and Tier Ones. “I can imagine the suppliers’ frustration. If every OEM has its own XML you would need to be able to understand each different XML format and have a kind of virtual machine in your system,” he said.◆

PLC...

Dave Wright is director of advanced engineering at Delphi Packard. “We evaluated Yamar’s parts and built some demonstration hardware. But we are waiting to see if the market really does surface. One potential application is using PLC as a redundant communications channel in some sort of by-wire configuration. But by-wire is coming along pretty slowly. We will stay in touch with the technology and don’t believe we have to make it commercially available this year.”

High-Speed PLC for Video

Valeo reports that several carmakers are interested in its high-speed PLC technology, which can operate at speeds up to 50 Mbps, as an alternative to optical fiber or shielded twisted pair wiring to carry video signals from a camera to a monitor. Shielded twisted pair cable is expensive, from $10 to $20 installed, depending on length and the type of cable used, says Valeo. And that makes a good business case for the high-speed PLC transceivers, which would substitute for the cable. One transceiver is needed at the camera and one at the monitor. A second camera would require just one more transceiver.

According to Valeo, several carmakers, in Europe and the States, are funding about 10% of Valeo’s high-speed PLC technology development costs. If orders are received, shipments could start in 2009 or 2010, once an ASIC implementation of the transceiver is validated.

Valeo developed the high-speed PLC with the help of SPiDCOM Technologies, a fabless semiconductor company based in Paris, and a member of the Homeplug Power Alliance. Valeo has been adapting Homeplug’s OFDM (orthogonal frequency division multiplex) technology for use in automotive applications. “Homeplug is a standard PLC solution used in home networking,” noted Mark Semelle, a Valeo project manager.

The industry defines OFDM as a modulation technique for transmitting large amounts of digital data over a radio wave. OFDM works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver. OFDM reduces the amount of crosstalk in signal transmissions. WLAN and WiMAX technologies use OFDM.

continued on page 8
Valeo

**Background**

Through decades of diversification, followed by international expansion and targeted acquisitions, Valeo has grown from a small distributor of brake linings and clutch facings in the 1920s, to the world’s ninth-largest automotive OEM component supplier in 2006. Today Valeo operates 129 production sites and 68 research and development centers in 29 countries and employs more than 70,000 people. Valeo engineers filed 562 patents in 2006.

While Valeo sales have grown at the rate of 10.5% per year over the last ten years, sales have been flat since 2001. North American sales have declined from 37% of Valeo’s business in 2004, to 13% of its business in 2006. In North America, Valeo says it will grow its business not so much with the Detroit carmakers, but with the transplant carmakers, whose businesses have been growing faster.

Valeo plans to turn over a sizable portion of its business portfolio; it plans to divest businesses with sales totaling about €2 billion, while it acquires businesses with sales totaling about €2 billion. "These won’t be as big as some of the acquisitions we’ve made in the past," explained Kate Philipps, Valeo communications director. "Our acquisition strategy is very targeted. We’re focused on our three domains—either for complementary technologies or to help us for more than half of total sales. Seventy-three percent of sales in 2006 came from products that Valeo says are commodities, which produce only slim margins.

Between now and the end of 2009, Valeo plans to divest businesses with sales totaling about €2 billion, while it acquires businesses with sales totaling about €2 billion. "These won’t be as big as some of the acquisitions we’ve made in the past," explained Kate Philipps, Valeo communications director. “Our acquisition strategy is very targeted. We’re focused on our three domains— either for complementary technologies or to help us achieve a global leadership position in our product lines. We’re not looking to go into a whole new business.”

**Valeo Nixed Merger with Visteon**

In 2006 Valeo studied the possible acquisition of Visteon but decided not to proceed with the deal. “Valeo concluded that the acquisition was too risky and would endanger the company,” noted Ms. Philips, adding, “The board decided there were financial, legal and operational
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in the timeframe set by Valeo.

pany, but no acceptable offer was received

imated with a private equity investor who

Capital Management owned 18.1% of

European Special Opportunities Master

2007 by Valeo’s major shareholder, Pardus

sue the merger with Visteon, that subject

as the primary customer.” Ford lost $12.7

and Switzerland. It also has booking busi-

in sales 2004

Engine cooling 15.4% 3.9%
Climate control 15.3% 5.2%
Lighting systems 11.8% 5.4%
Electrical systems 10.8% 4.9%
Wiper systems 10.2% (6.0%)
Switches & detection systems 8.2% (2.8%)
Transmissions 7.5% 4.8%
Security systems 7.1% 4.3%
Electronics & connective systems 5.9% (6.0%)
Compressors 4.3% 50.4%
Engine management systems* 3.5% (3.8%)

All product families* 100.0% 5.2%

CAGR from 2005

risks— it would have heavily indebted

Valeo, and the combined companies

would have been very dependent on Ford

as the primary customer.” Ford lost $12.7

billion in 2006 and $282 million in the

first quarter of 2007.

Despite the board’s decision not to pursue

the merger with Visteon, that subject was again brought back to the table in

2007 by Valeo’s major shareholder, Pardus European Special Opportunities Master Fund, which owns 15.5% of Valeo. Pardus Capital Mangement owned 18.1% of Visteon as of June 2007. “Valeo’s position has not changed. The acquisition would be too risky,” Ms. Philips reiterated.

During the spring of 2007, Valeo negotiated with a private equity investor who expressed interest in a buyout of the company, but no acceptable offer was received in the timeframe set by Valeo.

New Products Will Fuel Sales Growth

Martin Haub is Valeo’s group vice president for R&D and product marketing. Begun in 2001, product marketing is a relatively new responsibility at Valeo. Its main objective is to study end-user behavior to really understand what the market needs in terms of products and pricing.

M. R. Haub explained which products within Valeo’s three product domains—Powertrain Efficiency, Driving Assistance and Comfort Enhancement—will have the greatest impact on future sales.

In Powertrain Efficiency, starter alternators, engine cooling and dual-clutch assemblies are showing strong growth potential. In Driving Assistance, Valeo’s park assist, high-beam control and blind spot detection show promise. Among the new products in the Comfort Enhancement domain, M. R. Haub is seeing strong interest among carmakers in Valeo’s new Smart Car Key security system.

Belt-D riven Starter A lternator R everseable System (StA RS)

In 2005, Citroën became the world’s first carmaker to feature a start-stop system with the introduction of a Valeo belt-driven starter alternator in its C3 Stop & Start vehicle. The system stops the engine just before the vehicle comes to a standstill and starts the car automatically as soon as the driver takes his foot off the brake pedal to move forward again. In 2006 Citroën made the starter alternator available on the C2 as well. A according to Citroën, the combination of its Senso-

Drive gearbox and Valeo technology has resulted in a 6% to 15% reduction in fuel consumption and CO₂ emissions, depending on traffic congestion.

Valeo’s starter alternator will next be employed on the Smart fortwo micro-hybrid vehicle from DaimlerChrysler; production will begin later this year. Valeo also has booked business with at least one other German carmaker.

In 2009 Valeo expects to ship somewhere between 50,000 and 100,000 starter-alternator systems, including the electronic control units.

Carmakers around the world have shown a great deal of interest in the Valeo starter alternator, which operates at 14 volts, is air cooled and can easily be mounted in place of the conventional alternator on engines of any size, up to five liters. The starter alternator silently starts the vehicle in one-third the time a conventional starter takes. Thus far, Valeo has equipped 60 demonstration vehicles with prototype starter alternators. Valeo believes that its early production experience and the maturity of its technology will soon lead to more production orders for its starter alternators.

The next two steps in the product road map will lead first to a starter alternator that packages the electronics, not in a separate box as is required today, but with the machine. Following the improvements in electronics packaging will be a starter alternator that can accommodate regenerative braking. That system will make use of ultracapacitors to store some of the kinetic energy for later use.

U ltimate Cooling

Valeo is anticipating a significant jump in sales of new engine cooling products that are inspired by the more stringent Phase 2 requirements of the pedestrian protection directive of the European Commission. Phase 2 provisions are scheduled for implementation beginning in 2010.

Martin Haub explained: “The need for passenger protection has inspired us to launch a completely new way of doing engine cooling, which we call Ultimate continued on following page
Cooling: Our main idea is to switch from air-cooled heat exchangers to liquid-cooled heat exchangers. This allows carmakers to remove heat exchangers from the front of the vehicle where they could cause harm in pedestrian crashes and instead package them as part of the engine. Simplifying vehicle assembly and improved performance are additional benefits of the new configuration.

One Ultimate Cooling component that will hit the market sooner than 2010 is a charge air cooler that uses liquid rather than air to cool the turbo-charged air coming into the engine. Because cool air is denser than hot air, more efficient combustion can be achieved. “The demand for turbo-charged engines is exploding, and eventually everybody who needs charge air coolers will switch to this approach,” predicted Mr. H. Haub. “Since the cooler is mounted right on the engine, it takes less time for the air to reach the engine, and that helps to solve the problem of turbo lag—the time it takes the engine to respond to the gas pedal. Typically, this is spec’ed in when a new engine is set up.”

Valeo is also developing an air intake module that integrates all relevant heat exchangers, valves and controller into a single module that can ride on the engine. That product will be ready in 2010 or so thereafter.

A new engine cooling component with a promising future is Valeo’s Themis valve, a four-way, rotary, electronic water valve that replaces the wax thermostat. The valve includes software that precisely controls the flow of coolant between engine, radiator and heater core to reduce fuel consumption and emissions and improve thermal comfort in the cabin. Valeo expects its first production order for the Themis valve soon.

**Dual Clutch**

A iso promising in terms of expected sales, says Mr. H. Haub, is Valeo’s new dual-clutch assembly, which makes manual transmissions even more fuel efficient.

When one clutch is open, the other is closed; there is no drop-off in power as the transmission shifts between gears. “The manual transmission has been more fuel efficient than an automatic, assuming you know when to shift. But not all drivers know how to shift properly, which is why it is best done automatically,” said M. H. Haub. “The dual-clutch arrangement makes for smoother shifting.” A key element in the dual clutch is the motor-driven, self-adjusting actuators, which maintain a constant actuation force during the life of the vehicle.

Fewer than ten prototypes of the Valeo dual-clutch assembly have been built, but more are in the works, given the high level of interest that carmakers in the U.S., Asia and Europe have shown in the product. Valeo expects to receive its first dual-clutch production orders this year.

**Park4U Park Assist**

Yet another promising new product is Valeo’s Park4U ultrasonic parking system.
that automatically steers the vehicle into parallel parking spaces. Park4U was launched in March 2007 on the Volkswagen Touran as an option, which thus far has been chosen by roughly 15% of Touran customers. Park4U includes an on-off switch, electronic control unit plus 10 ultrasonic sensors, one on each side and four each in the front and rear bumpers. The parking feature, including the hill-hold feature—not supplied by Valeo—is priced at €650.

Valeo’s Park4U system will soon be installed on other Volkswagen models, those that are light enough for electric power steering. Valeo has orders for the system from three other European carmakers and is negotiating potential orders with some non-European carmakers.

While driving at a maximum speed of 30 km/h, Park4U scans both sides of the street for parking spaces. Once a spot has been identified, the driver stops the vehicle and puts it into reverse, thereby activating automatic steering. The driver, assisted by the front and rear ultrasonic sensors, remains responsible for accelerating and braking while the car steers itself into the parking space. The maneuver can be interrupted at any time by braking or simply taking over the steering wheel. Parking takes no longer than 15 seconds. Manoeuvring back and forth multiple times if necessary, the system can park in a space that’s just 70 cm longer than the vehicle. Valeo is the world’s leading maker of ultrasonic parking systems.

Focus on Quality

Along with cost, global presence and innovation, quality is one of Valeo’s four “success factors.” By the end of 2006, Valeo had improved its quality performance to customer returns of 15 parts per million, a twelve-fold improvement from the end of 2003 when it suffered 185 parts per million customer returns. In the fourth quarter of 2006, 63 of Valeo’s 129 production sites had reached quality levels less than 10 ppm returns, including 15 sites that had 0 ppm. In 2007 Valeo won five awards from Toyota, including the Superior Performance Award for quality.

**Valeo’s Technology Partners**
- International Rectifier: Power electronics systems
- Iteris, a subsidiary of Odetics: Image processing for lane departure warning systems
- Raytheon: Radar blind spot detection
- IBM: Software development
- Jabil Circuit: Printed circuit board production

**BeamAtic High-Beam Control**

Four European customers are testing vehicles equipped with a prototype of Valeo’s BeamAtic t system, which uses a video camera packaged behind the rear-view mirror to automatically switch between high- and low-beam headlamps according to traffic conditions. “With this product we feel we can offer synergies in the market, because we make not only the camera but also the headlamps,” said Mr. Haub.

Gentex’s SmartBeam headlamp control system has been in production vehicles since 2004, but Mr. Haub believes that Valeo’s BeamAtic system is superior. “We have tested both and the Valeo system is much less likely to switch to low or high beams erroneously,” he said.

Next Valeo is developing a progressive version of the BeamAtic system that will continuously adjust the headlamp’s shutter between high and low beam in order to shine as much light as possible on the road without dazzling other drivers. The same camera could be used also to modify the high beams according to the steepness of hills or to automatically switch on the fog lights. Valeo’s LaneVue lane departure warning system, which Valeo has been supplying to carmakers since 2004, also depends on video camera technology.

**Blind Spot Detection**

Valeo is expecting strong sales from another important new product, radar blind spot detection, which was developed by Valeo Raytheon Systems, a joint venture which is 77.2% owned by Valeo. The multi-beam radar technology comes from Raytheon; the automotive engineering comes from Valeo. Valeo is already shipping the system to General Motors for installation on the 2008 Cadillac STS and Buick Lucerne. In a separate deal, Valeo will start supplying the system to a European carmaker at the end of 2007 or the beginning of 2008.

The system continuously monitors the rear blind spots on both sides of the vehicle, up to 10 meters away. When a vehicle is present in either blind spot, for example an overtaking vehicle, the driver is alerted to this potential hazard by a visible icon displayed in the side view mirror.

**Two-Way Key**

Valeo says that a number of carmakers are interested in its keyless entry system that goes beyond simply identifying the key’s presence in the vehicle and can now include two-way communications. “Now you can add to this key a display and some buttons, and you can do all sorts of things,” explained Mr. Haub. “You can check status of the vehicle. Is it locked? What is the fuel level? How hot is it? Then you can send commands to the vehicle, for example, to activate pre-ventilation. Furthermore, you could use it to connect to your home computer via a USB connection, download some information on the next navigation route and load that in the vehicle’s navigation system. Or you could download MP3 music files.”

In addition to the key, Valeo can supply a lot of the other components of the locking system including latches, steering column locks, antenna and sensors. Presently in development, the two-way keyless entry systems could be made ready for the market within three years.

**IBM-Valeo Joint Development Center**

Valeo Interbranch Automotive Center (VIA S), a two-year-old Valeo-IBM alliance, is developing automotive embedded software and software processes on behalf of future Valeo products, including chassis control systems. IBM is supplying software development expertise in the form of tools and training, as well as 30 of the engineers who presently staff the center. At the end of 2006, VIA S employed more than 100 engineers working on 120 projects. VIA S was certified CMMI level 3 in less than 18 months.
"We adapted OFDM technology first [so it will] meet automotive EMC (electromagnetic compatibility) requirements," said Anne Laliron, Valeo product manager for connective systems. "Secondly, we wanted this technology to be size and cost compliant with automotive requests. If you take this technology in home networking, it is expensive, but we’ve created a cost-effective version."

EMC issues and bandwidth limitations could limit the applications of PLC in Mr. Baltaji’s assessment. Sophisticated noise and error reduction strategies, and possible shielding requirements could increase system costs. Transmitting image data at 50 M bps requires compression of the signal and is suitable only for small, low-resolution displays such as might be found on a rearview mirror, he suggested. In Mr. Baltaji’s opinion, because the high-quality, color-intensive displays found in today’s high-end vehicles require unpressed data and therefore higher bandwidth, PLC is not yet suitable for high-quality video.

### Vehicle Maker and Supplier Ten-Year Growth Rates

The most important decision any automotive electronics supplier can make is which customers to serve. Obviously, some of the most desirable customers are the ones that are the biggest and the ones that have the fastest-growing appetite for the products suppliers can deliver. Given those criteria, Suzuki, Mercedes, Honda, Hyundai-Kia, PSA, and Toyota are the planet’s six most desirable customers. Those companies showed the highest annual growth rate during the last decade.

Looking at growth by region, Asian carmakers grew the fastest over the 10-year period, growing unit production 4.9% per year and accounting for 31% of the world’s vehicle production in 2006. U.S. carmakers grew the slowest, at just 0.6% per year over the 10-year period. Europeans grew at 3.1% per year.

Among the major tier-one electronics and electrical parts suppliers, the fastest growing over the last ten years, largely through acquisitions, have been Siemens VDO, Hitachi Automotive Systems, and Continental.

### Key Acquisitions 1996 - 2006
- **Siemens** acquired Mannesmann VDO in 2001; Huntsville Electronics in 2004.
- **Hitachi** now owns all of Unisys, JECs, Xanavi Informatics, Clarion and Tokico.
- **Continental** acquired ITT Teves in 1998, Temic in 2001 and Motorola ACES in 2006. Conti announced the acquisition of Siemens VDO in July 2007; transaction to be completed by year end 2007.

### PLC4TRUCKS
A according to Derek Rotz, an electrical engineer at Freightliner, PLC has been used in truck trailers since March 2001, an outgrowth of the U.S. mandate for in-cab warning lights if the trailer’s ASB fails. PLC4TRUCKS is an SAE B-based bi-directional networking standard using spread-spectrum power line communications. In addition to ASB warning, the SA B standard can also be used to monitor lift axle, door latch, tire pressure, and/or trailer refrigeration temperature.

### Table: Vehicle Maker and Supplier Ten-Year Growth Rates

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<td>2,858,000</td>
<td>5.7</td>
<td>3,238,346</td>
<td>4.6</td>
<td>1.3%</td>
</tr>
<tr>
<td>Total of above (Asian)</td>
<td>13,708,455</td>
<td>27.2</td>
<td>22,010,517</td>
<td>31.0</td>
<td>4.9%</td>
</tr>
<tr>
<td>GM</td>
<td>7,619,000</td>
<td>15.1</td>
<td>8,743,248</td>
<td>12.3</td>
<td>1.4%</td>
</tr>
<tr>
<td>Ford</td>
<td>6,379,000</td>
<td>12.7</td>
<td>6,563,092</td>
<td>9.3</td>
<td>0.3%</td>
</tr>
<tr>
<td>Chrysler**</td>
<td>2,932,000</td>
<td>5.8</td>
<td>2,700,000</td>
<td>3.8</td>
<td>-0.8%</td>
</tr>
<tr>
<td>Total of above (U.S.)</td>
<td>16,930,000</td>
<td>33.6</td>
<td>18,006,340</td>
<td>25.4</td>
<td>0.6%</td>
</tr>
<tr>
<td>Mercedes (Car and Truck)</td>
<td>984,760</td>
<td>2</td>
<td>1,788,797</td>
<td>2.5</td>
<td>6.2%</td>
</tr>
<tr>
<td>PSA</td>
<td>1,979,008</td>
<td>3.9</td>
<td>3,357,000</td>
<td>4.7</td>
<td>5.4%</td>
</tr>
<tr>
<td>Volkswagen*</td>
<td>3,983,152</td>
<td>7.9</td>
<td>5,659,578</td>
<td>8.0</td>
<td>3.6%</td>
</tr>
<tr>
<td>Renault</td>
<td>1,806,177</td>
<td>3.6</td>
<td>2,346,319</td>
<td>3.3</td>
<td>2.7%</td>
</tr>
<tr>
<td>BMW Group</td>
<td>1,145,231</td>
<td>2.3</td>
<td>1,368,838</td>
<td>1.9</td>
<td>1.8%</td>
</tr>
<tr>
<td>Fiat</td>
<td>2,550,000</td>
<td>5.1</td>
<td>2,363,986</td>
<td>3.3</td>
<td>-0.8%</td>
</tr>
<tr>
<td>Total of above (Europe)</td>
<td>12,448,328</td>
<td>24.8</td>
<td>16,882,500</td>
<td>23.7</td>
<td>3.1%</td>
</tr>
<tr>
<td>Others</td>
<td>7,336,217</td>
<td>14.4</td>
<td>14,028,319</td>
<td>19.9</td>
<td>6.7%</td>
</tr>
<tr>
<td>Total global production</td>
<td>50,425,000</td>
<td>100</td>
<td>70,927,676</td>
<td>100</td>
<td>3.5%</td>
</tr>
</tbody>
</table>

*Not including Porsche
**The acquisition of Chrysler by private equity firm Cerberus is expected to close in early August.

Data: 1996 production data from OICA; 2006 production data from Automotive News, DaimlerChrysler

### Table: Key Acquisitions 1996 - 2006

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Year</th>
<th>Acquisition Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hitachi Automotive Systems</td>
<td>1998</td>
<td>now owns all of Unisys, JECs, Xanavi Informatics, Clarion and Tokico.</td>
</tr>
</tbody>
</table>

Note: unless otherwise noted, currency conversion to U.S. dollars is at current exchange rates.

1997 U.S. dollars
1998 U.S. dollars
FYs ending in March 1997 and March 2007
As of 2005
Delphi Automotive plus Delco Electronics