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POF Tackles Automotive Requirements

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Car makers looking to implement in-vehicle plastic fibre networks require high-bandwidth links, low costs and complete reliability, especially as they begin to exploit this optical infrastructure for safety-critical applications. Tami Freeman takes a look at some of the latest developments in the world of wired-up cars.

Take a close look at the specification sheet of any top-of-the-range car nowadays and one thing is clear -- more and more vehicles are exploiting plastic optical fibre (POF) to connect up the ever-increasing number of in-car electrical devices. Whether it's a Rolls Royce or a Smart car, POF is becoming a must-have option for in-vehicle networks.

The benefits for the automobile manufacturers are clear: POF offers a high operating bandwidth, increased transmission security, low weight, immunity to electromagnetic interference, and ease of handing and installation.

Crucially, it's also a low-cost option, with both the fibre itself and the associated components coming in at a fraction of the cost of their pure silica counterparts.

It's not uncommon to find 10 or 20 electrical devices hooked up within a car, including radios, CD and DVD players, navigation systems, Bluetooth interfaces, telephones, voice recognition systems, video gaming consoles and TV tuners. To meet the demands of data transfer between these multimedia devices, many car makers employ a 24.8 Mbit/s data bus protocol called Media
Oriented Systems Transport, or MOST.

And it's not just navigation and entertainment functions that can exploit POF. BMW has developed a 10 Mbit/s protocol called ByteFlight, which it uses to support the rapidly growing number of sensors, actuators and electronic control units within cars. Unlike MOST, which employs real-time data transfer, ByteFlight is a deterministic system in which the focus is on making sure that no data is lost.

"Initially, POF was used in cars for entertainment systems, then BMW decided to use it for airbag actuation," explained Paul Polishuk, president of optical comms consultancy Information Gatekeepers and a director of the POF trade organization, POFTO. "That's a whole different mindset because now it has to

be reliable enough for safety-critical applications. We're seeing POF gaining
the automobile manufacturers' confidence enough to be used in mission-critical applications."

Standard approach

DaimlerChrysler (formerly Daimler-Benz) first introduced POF into its S-series Mercedes-Benz back in 1998, using a simple optical data bus system called D2B. It soon became apparent that a more sophisticated protocol was needed, and that such a unified standard would also guarantee economies of scale and help
drive prices down. With this in mind, DaimlerChrysler teamed up with BMW, IC specialist OASIS SiliconSystems and in-car entertainment systems vendor Harman/Becker to form the MOST Cooperation.

The goal was to develop a unified data bus standard for automobiles using POF as a transmission medium. Currently, 19 car makers are members, and there are over 6 million MOST nodes on the road, with over 10 million nodes/year predicted from 2005 onwards. Over 22 models of car are equipped with MOST systems, with the Mercedes E-Class, BMW 7 Series, Porsche Cayenne, Saab 9.3, Audi A8, and Volvo XC-90 among the first to deploy the technology commercially.

"With MOST, the automobile industry developed a unified standard that everybody abides to, with the intention of driving cost down," said Polishuk. "You can now buy a 26 Mbit/s transmitter--receiver pair for less than $7. They hope in a year or so to have that down to $3. If you look at datacoms or telecoms, you can't buy a transmitter--receiver pair for less than $100."

Cost reduction is the logical outcome of increased volumes. "The ability to produce high-volume, automotive-quality components was the main reason that MOST and ByteFlight became so successful in the automotive industry," explained Hans Hurt, director for concept engineering and business development at German chip maker Infineon Technologies. "We have a run rate approx of 400,000 components a week for ByteFlight and MOST."

Infineon currently boasts a 95% market share for MOST transmitters and receivers (although it should be noted that the firm has just announced the sale of its fibre optics business unit to Finisar, a US manufacturer of optical subsystems and test gear, in a deal that is expected to close in the third quarter of 2004).

The company's MOST transmitter is based on a 650 nm LED and is suitable for data rates of up to 50 Mbit/s, while the receiver is a photodiode with pre/postamplifier. The devices operate at 5 V and boast an operating temperature range from --40 to 85°C. For ByteFlight, Infineon manufactures a bi-directional transceiver for transmission data rates of up to 10 Mbit/s and distances of 50 m. The transceiver is based on a 650 nm LED and a photodiode

with preamplifier. It also offers a temperature range of --40 to 85℃ and operates at 5 or 9 V.

There are now also more than 70 consumer electronic devices with MOST interfaces on the market. And last August, MOST was the first networking technology to be fully approved by the DVD Copy Control Association to carry copy-protected DVD video programmes.

Keep it safe

The ByteFlight protocol also arose from a collaboration, although BMW is the only car maker currently deploying the technology. Safety-critical systems need deterministic protocols with fault-tolerant behaviour. ByteFlight guarantees high data integrity at a data rate of 10 Mbit/s and an information update rate of 250 µs.

ByteFlight uses a star network configuration with an intelligent star coupler, and bidirectional communication over POF. The transceiver chip is integrated into the optical connector. Other characteristics include collision-free bus access, guaranteed latency for a certain number of high-priority messages, high flexibility, easy system extension, dynamic use of bandwidth and low system cost.

BMW's Series 7 models implement ByteFlight for control of the car's air bag systems. The vehicle contains 12 sensors (velocity, acceleration or pressure) distributed in a star system and linked via POF. "The system operates as a computer cluster with distributed functionality in order to evaluate the sensor data and fire the required air bags in case of an accident," explained a BMW spokesperson. BMW only uses ByteFlight to control thn airbag system and employs MOST for distributed networking of the vehicle's information and entertainment systems.

While ByteFlight addresses many safety features, it is not necessarily suited to use in the drive-by-wire systems touted for use in next-generation automobiles. For such advanced control applications, car manufacturers are looking to an emerging standard called FlexRay.

FlexRay was instigated by BMW and DaimlerChrysler, who joined forces with Philips and Motorola in September 2000 to form the FlexRay Consortium. Since then, three more core partners have joined: Bosch, General Motors and most recently Volkswagen.

Drive-by-wire applications (steer-by-wire, brake-by-wire and gear shift-by-wire) replace the mechanical and hydraulic controls with fibre or electrical connections. Total reliability is imperative -- the network simply must not fail. FlexRay addresses these safety-critical issues by offering a deterministic and fault-tolerant communication layer with guaranteed latency time and jitter.

FlexRay can use the same 10 Mbit/s optical physical layer that is already available for ByteFlight. But the protocol is defined independent of the topology and physical layer, enabling the use of both electrical and optical transceivers. Currently, Philips is developing a dedicated FlexRay electrical physical layer.

"The good thing about this is that when FlexRay comes to the car, Infineon has, it already done a lot of work with our ByteFlight transceiver," Hurt explained. "This enables us to easily address the FlexRay topology. There are a lot of similarities. For example, the data rate is the same, 10 Mbit/s, and they are both deterministic systems."

BMW has developed support for applications such as brake-by-wire already, although there are no FlexRay-equipped cars on the road yet. The first system tests will be performed later this year and BMW expects to have the FlexRay technology in series production in 2006.

High-speed transfer

As the number and complexity of electrical devices in the car continues to increase, some manufacturers foresee a need to ramp the existing 25 Mbit/s data rate limit up to 150 or even 400 Mbit/s. This is where a newer protocol, IDB-1394, comes into play. IDB-1394 is an automotive version of IEEE-1394 (also known as FireWire), a technology that has already gained wide acceptance in the consumer electronics industry.

"IDB-1394 differs from MOST and ByteFlight in several ways," explained Arlan Stehney, executive director of the IDB Forum. "Firstly, IDB-1394 is designed for much higher-speed data transfer, up to 400 Mbit/s. The physical layer is also unique, with specific connectors on the POF design."

Developed by US and Japanese automobile manufacturers, IDB-1394 is optimized for both asynchronous and isochronous data transfer. The topology also permits existing IEEE-1394 consumer electronics devices to interoperate with embedded automotive-grade devices. While the standard is initially designed for POF applications, the IDB Forum is also looking to develop a copper version. "Manufacturers have asked for a complementary specification that includes copper, so that a hybrid network using both POF and copper can be used where it's more cost-effective," Stehney explained.

So what will IDB-1394 offer car makers and users? For starters, it will enable high-speed transfer of digital information, including high-density TV, uncompressed video applications such as blind-spot detection cameras, audio applications like Super Audio CD and transfer of navigation information from a DVD drive to a navigation system.

"Manufacturers are already considering wide-area high-speed wireless networks and how such networks can link vehicles and their devices into the infrastructure," added Stehney. "These will likely be nodes on an IDB-1394 network that will provide streaming content at 50--100 Mbit/s."

Companies such as Infineon are participating in the device standardization. "At the moment we are just defining the specifications for the optical transceiver," said Hurt. "From the system side it's a multimedia system like MOST, whereas ByteFlight and FlexRay on the other side are more security-focused."

Stehney says that IDB-1394 is currently in production development in select vehicle programmes, and will be introduced in model 2006--2007 vehicles in Japan and Europe. Several vehicle manufacturers are already working with IEEE-1394 to benchmark performance and to gain familiarity with the technology before implementing the protocol using a full fibre-optic network.

Hotting up

Plastic fibre itself has undergone some revolutionary developments over the last few years. Poly(methyl methacrylate), or PMMA, fibre offers an attenuation of below 150 dB/km at 650 nm and can handle 10 Gbit/s data rates. The move from step-index PMMA to a graded-index profile increased the fibre's bandwidth range, while perfluorinated PMMA, in which the lossy CH group is replaced by CF groups, offers both high bandwidth and low attenuation.

But PMMA fibre still has one key limitation: it can only be used at temperatures of up to about of 85ºC. And in cars, things can get a lot hotter. Temperatures in the roof module can easily reach 105ºC, while 125ºC is not unusual in the engine compartment. As a result, many car manufacturers are looking for fibre that is specified at temperatures of 125ºC.

One solution is to use a hybrid fibre called polymer-clad silica (PCS) fibre. PCS fibre offers many of the advantages of POF -- large core size (200 micron) and the associated ease of connectorization -- but it is also capable of high-performance operation at up to 125ºC. The combination of a silica core with a hard polymer cladding offers the best of both worlds: low-loss transmission and superior fibre strength.

In a recent presentation, DaimlerChrysler's Eberhard Zeeb outlined the challenges for future MOST networks. As well as a higher temperature range, the fibre installation needs to be compatible with standard electrical wire installations, with no restrictions on length or bending radii. Other needs include easy network expansion, plug-and-play components, low cost and faster data rates.

Zeeb explained how PCS meets many of these requirements. For starters, it offers a bending radius within the cable harness of less then 10 mm, compared with over 25 mm for PMMA fibres. Meanwhile, PCS's low attenuation of 10 dB/km at 650 nm and 8 dB at 850 nm minimizes restrictions on length. PCS also offers double the tensile strength of POF and up to ten times greater long-term strength and flexing capability (according to some manufacturers' tests). On the downside, PCS is

approximately twice the cost of POF.

Another attractive feature of PCS is that it can be used at 850 nm, where the attenuation of PMMA POF is high (more than 1000 dB/km). This enables manufacturers to employ vertical-cavity surface-emitting lasers (VCSELs) as transmitters. "With a VCSEL you have a much higher power budget in the whole system, which enables car manufacturers to be more flexible in the harnessing of the car," said Infineon's Hurt. "With POF we use 650 nm LEDs, and for PCS it would be 850 nm VCSELs."

Both the MOST and ByteFlight protocols can be employed over PCS. It's also worth noting that PCS is compatible with standard POF transceivers. "You could pull out the plastic and put in the PCS with the same transmitter/receiver pairs," said Polishuk. "That's one of the advantages that DaimlerChrysler is touting."

BMW also supports the activities to bring PCS into cars, although, to date, none of BMW's cars are equipped with PCS. "PCS has a good chance of being the follow-up medium for POF," explained a BMW spokesperson. "We can imagine using PCS in the future, not only for MOST networking, but also for safety critical networks or display links."

According to a report by IGI Consulting, PCS will start to be deployed in 2007, with a potential market of $51m (107m fibre-meters). The POF community is, however, also working on some materials that could go to higher temperatures. "POFTO has taken the position that POF and PCS will work in concert with each other," Polishuk added. "We see them not as competitors, but as complementary."