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How automotive ENGINEERS PLAN TO BOOST BANDWIDTH in cars of the future, p78

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COVER STORY

For automakers, it's BANDWIDTH, BANDWIDTH, BANDWIDTH

To reduce complexity and prepare for the onslaught of more electronic features, automotive engineers are looking at faster, more efficient electrical architectures.

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Pipe flow: It's a hydraulics term, only remotely associated with the likes of microprocessors and software. But over the next ten years, "pipe flow" is going to be transformed into an electronics term, as automakers face a computing dilemma that will dwarf anything in the history of the desktop world. Their challenge, in essence, is to push tens of millions of bits of data per second down an electronic pipe, allowing scores of microprocessors to "talk" to each other, enabling flawless operation of brakes, throttles, radios, CD players, door locks, window lifts, engines, transmissions, seat motors, heaters, air conditioners, windshield wipers, airbags, cell phones, steering wheels, and countless other items, so that not one life is ever lost because a data packet got hung up somewhere, causing the brakes to fail.

"Over the long term, we're going to need something with a lot more bandwidth."

—Hans De Regt, Philips Semiconductors

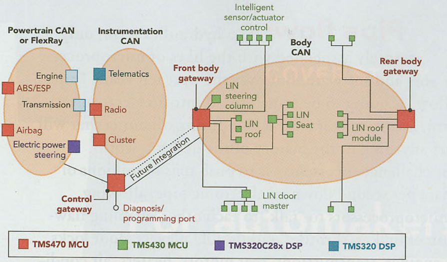
To accomplish that, automakers are going to need a big electronic data pipe, bigger than the 1 Mbit/sec offered by today's CAN (controller area network) buses, and maybe even bigger than the 20 Mbits/sec of the industry's emerging FlexRay bus. In essence, they'll need a fat pipe capable of gulping down millions—maybe billions—of bits of data per second and spitting those bits back out to the proper locales. No one knows for sure, but a few forward-thinking engineers believe that the industry would do well to start considering bandwidths in excess of 100 Mbits/sec, now.

"For the short term, we still see CAN as the major automotive bus," says Hans De Regt, marketing director for Philips Semiconductors' Automotive Business Line. "But over the long term, we're going to need something with a lot more bandwidth."

Indeed, the computing necessities are almost mind-boggling, not only because of the sheer volume of data, but because of the requirement that the microprocessors talk to one another. Ultimately, engineers foresee a day when the forward-looking radar sensors will talk to the brakes and airbags, when cell phones will communicate with radios, and when the rain-sensing wipers will talk to antilock brake modules.

Doing that, of course, requires a more centralized system. It will no longer be sufficient to discretely control a single system with its own dedicated, isolated microcontroller. "We want to look at the entire vehicle, from end to end, as one big system," notes Pat Jordan, director of systems engineering for Motorola Corp's Global Software Group. "And today's bus architectures are inadequate for doing that."

Changing Requirements Lead to New Automotive Architectures and Partitioning



CAN will continue to serve as the databus for body, powertrain, and instrumentation applications in the next five years, but some engineers believe FlexRay could replace it in powertrain, especially as by-wire systems reach the market.

(Figure courtesy of Texas Instruments)

Beyond Buses

Predictably, there is disagreement over how to do it, or even whether it needs to be done at all. But in some quarters, a sense of urgency is growing. The auto industry, after all, typically works five years ahead, and with each successive year, electronic systems are growing maddeningly more complex. That's why most automotive engineers have begun pushing hard in an effort to settle on a technology, improve it, and standardize it.

Until this year, a growing number of automakers had been migrating toward FlexRay as a potential solution to some of those growing complexity-related issues. FlexRay, after all, offers bandwidths approximately 10 times greater than those of the CAN bus.

Late last year, however, Motorola Corp. introduced an alternate concept. Switch fabric, a technology that has made its name in telecommunications switches and relays, could have potential as an automotive network because it offers bandwidths 100—and possibly even 1,000—times greater than those of CAN, the company says.

"We looked at the Internet and asked, 'How can we bring those features of the Internet into the communications architecture of a vehicle?'" Jordan says. "And we saw switch fabric as the best way to do that."

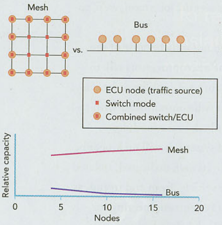
In essence, Motorola's switch fabric is not a databus. Rather, it is a mesh of interconnected nodes, in which any single node can "talk" directly to any other node by navigating a direct path across the wire mesh. The concept, however, is not co-opted directly from the Internet world. Instead, the computing giant has devised an automotive-centric "distributed switch fabric" concept, employing a limited number of nodes that operate like small packet data switches. This is accomplished primarily through software protocols, and by combining those protocols with the physical layers of other databuses, such as CAN or FlexRay.

The resulting level of speed is magnitudes ahead of anything available with existing databuses, such as CAN, J-1850, LIN, ByteFlight, or even FlexRay. Used with a CAN physical layer, for example, Motorola's distributed switch fabric can provide bandwidths of 1 Mbit/sec at each link, with as many as 256 links, resulting in an ultimate theoretical bandwidth of 256 Mbits/sec. Combining a FlexRay physical layer with the switch fabric protocol, the bandwidth soars even higher—to about 10 Mbits per link. With 200 links in the mesh, the result would be an ultimate bandwith approaching 2 Gbits/sec.

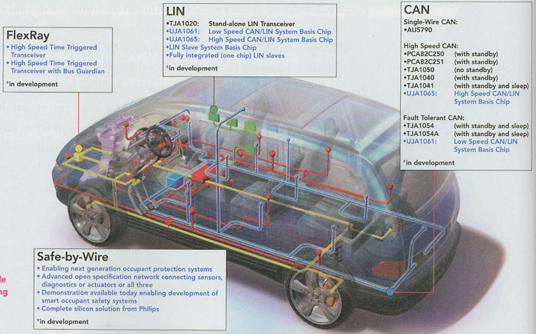
"All of the communications in a switch fabric are point to point, so all the links can communicate simultaneously," notes Jordan of Motorola. "Obviously, you can never utilize 100 percent of that, but that's true of any architecture. The point is, you get a lot more bandwidth with switch fabric than you do with CAN or any databus."

No More 'Baby Steps'

Ultimately, the bandwidth available from Motorola's switch fabric architecture is almost limitless. In the telecommunications



Switch fabric boosts bandwidth by enabling any single node to "talk" directly to any other node by navigating a direct path across the mesh.



Network	Bandwidth	Applications	Outlook
CAN	Less than 1 Mbit/sec	Powertrain, chassis, instrumentation	Available now
FlexRay	10-20 Mbit/sec	Drive-by-wire, body, powertrain	5-10 years out
Switch fabric	Into the gigabit range	Central vehicle backbone	15-20 years out

world, where switch fabrics are rapidly nearing acceptance, engineers are talking about bandwidths of 2 terabits/sec. No one has as yet dared associate such numbers with the auto industry, but Motorola engineers have acknowledged that their switch fabric protocol could offer speed gains of 1,000 times over CAN, which is today's most commonly used automotive bus structure.

Motorola engineers stress that their switch fabric concept is different because it is not a bus architecture. "With any bus architecture, modules on the bus have to have equal access," Jordan says. "Therefore, at some point in time, you're bound to run into a bandwidth issue."

Experts say that automotive engineers find the concept compelling, but are viewing it as a very long range solution. "It's a good way for the auto industry to deal with the bandwidth issues surrounding CAN," says Paul Hansen, publisher of *The Hansen Report on Automotive Electronics* (www.hansenreport.com). "But it's something you won't see for at least 10 or 15 years, if that."

Many automotive engineers also argue that CAN has stood the test of time during roughly two decades of automotive development, and that any new network will need to prove itself in a similar fashion. "When you bring any new network into a vehicle, you've got EMC (electromagnetic compatibility) issues to deal with, especially at higher bandwidths," notes Scott Monroe, systems architect for Texas Instruments' Mixed Signal Automotive Business Unit. "It still comes down to the fact that you're trying to transmit data at a high rate, and you're trying not to give off any electromagnetic emissions from the copper wire as it goes through the car."

Motorola engineers, however, believe that the time is right to look at switch fabric, especially as more automakers recognize that CAN may be running out of horsepower. "At this point, instead of taking baby steps, it might be time to look at the possibility of making a bigger change," Jordan says.

Shorter Term Solution

Such dramatic changes, however, are unlikely to be made before FlexRay makes its way into vehicles. FlexRay, originally developed as a bus for so-called "by-wire" automotive applications, was originally seen as a method for providing reliable operation for safety-critical systems. In particular, it was aimed at steer-by-wire and brake-by-wire systems, among others, because it offers high bandwidth and, in particular, fault tolerance. It has the backing of most of the world's biggest automakers, including General Motors, Ford, DaimlerChrylser, and BMW.

FlexRay is considered a strong candidate for such safety-critical applications because it incorporates a time-triggered software architecture (rather than event-driven), which ensures that there is always a slot for important messages. As a result, it provides a level of redundancy for steering, brakes, and other systems that will no longer have the inherent redundancy of hydraulics.

More recently, however, automotive engineers have begun to look to FlexRay to play a larger role in the vehicle. As a central backbone, they say, FlexRay could solve the bandwidth issues that are fast approaching as CAN nears its limit. Some engineers within General Motors and elsewhere want to use FlexRay to control powertrain, chassis, and airbags, as well as drive-by-wire systems. Once again, bandwidth is a key to such thinking: While CAN offers a data rate of less than 1 Mbit/sec, FlexRay's two-channel configuration offers 10 Mbit/sec per channel, for a total of 20 Mbit/sec.

Electronics engineers from all the companies stress, however, that CAN buses will continue to play a dominant role in electrical architectures for years to come. CAN technology, they say, is the product of tens of thousands of man-years, and automakers aren't about to abandon it soon.

"In ten years, CAN will still be the predominant bus in the majority of vehicles," notes Monroe of Texas Instruments. "The industry has too much of an entrenched infrastructure to drop it quickly."

Most engineers believe that the auto industry will slowly change its electrical architectures, most likely by employing a mix of protocols. FlexRay, they say, could eventually serve in body and chassis applications, LIN (local interconnect network) in lower-bandwidth applications such as door locks and window motors, Safe-By-Wire in airbags and other safety devices, and CAN may still hold its ground in powertrain.

Ultimately, however, they expect the number of nodes and the number of microcontrollers to decrease. Otherwise, they argue, system complexity could spiral out of control.

"In ten years, we expect to see big supernodes, with FlexRay for the high-bandwidth applications and LIN for sensing and actuating," notes De Regt of Philips Semiconductors. "The goal is to make a smaller number of nodes and combine more applications into single nodes."

Either way, most automotive engineers know they're going to need a bigger "data pipe." As they move toward forward-looking applications such as adaptive cruise control, collision avoidance, and automated lane-keeping, communication signals within the vehicle could increase by ten-fold. Under such conditions, the concept of a central electrical backbone—one that's not divided into sub-buses and gateways—will grow in importance.

"There's no way you could trust an entire vehicle to one of today's conventional buses," concludes Jordan of Motorola. "With today's buses, bandwidth is always going to limit you."

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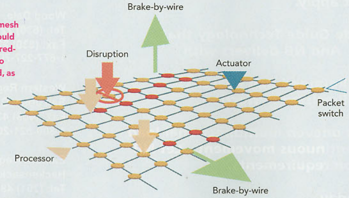
Motorola's switch fabric, a mesh of interconnected nodes, could boost bandwidth one-hundred-fold and enable engineers to wire the vehicle, end-to-end, as a single system.



WEB RESOURCES

//Check out the links below for more info//

- **Motorola switch fabric:** http://rbi.ims.ca/4395-538
- **FlexRay:** http://rbi.ims.ca/4395-539
- **CAN buses:** http://rbi.ims.ca/4395-540

CHART: DAN GUIDERA