HANSER

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XCP on FlexRay at BMW

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INTERVIEW

AdaptiveDrive in the new X5 utilizes sensors and performs computations to acquire data on vehicle speed, steering angle, longitudinal and lateral acceleration, body and wheel accelerations as well as their heights. The swivel motors of the stabilizer bars and electromagnetic valves of the shock absorbers are controlled based on this information. This provides full-time control of body roll and damping based on the given driving situation. The new BMW X5 is the first vehicle in the world to utilize FlexRay technology.

Use of XCP on FlexRay at BMW

This fall the first FlexRay production application will hit the streets. The Munich-based automotive manufacturer BMW is introducing the innovative bus system for the first time on its new X5 vehicle. From December 2004 to January 2006 tool producer Vector Informatik worked together with BMW on the FlexRay solution. FlexRay experts Martin Peteratzinger and Florian Steiner of BMW and Roel Schuermans of development partner and software provider Vector discussed their experiences in HANSER automotive.

Mr. Peteratzinger, why FlexRay and why now?

Peteratzinger: That was a strategic decision. We have already reached the limits of reasonable bus loads with CAN, and would otherwise need to install multiple CAN buses, and not just for high-end products. Our analyses indicated that up to eight CAN buses would be needed for just the powertrain and chassis areas in the next 7-series car. But we do not want to implement even more sub-buses; at some point they become unmanageable. Therefore, some years ago BMW decided to build up its development experience with FlexRay. We now have a foundation for future electrical systems and will expand them to include additional vehicle systems in upcoming car models. If we did not start on this now, we would have had to utilize a large number of CAN systems and sub-buses to carry us through, and this would last for many years due to the development cycles for car models.

Steiner: Another criterion of course is transmission rate. In the current application sensor signals are acquired and processed both by the central ECU and by the satellites. On the one hand, this decentralized approach leads to an increased demand for communication, and on the other hand shorter cycle times are needed on this and future architectures due to their separation of sensors, control system and actuator. In addition, many of the new functions and architectures place stricter requirements on real-time capability and communication availability. This can only succeed with a bus system like FlexRay.

Translated by Vector Informatik

Why did BMW chose suspension control as a pilot application?

Peteratzinger: FlexRay is a completely new development, and we had no knowledge base from other production projects. In this case, the first step was to build up this knowledge. It was therefore important for BMW to be able to quikkly apply this acquired knowledge and implement necessary changes during development. In a system such as an engine controller the adaptation effort would be considerable due to the large number of interfaces. This new suspension system has a well-defined and limited functionality. In a small team, together with our ECU suppliers and development partners such as Vector, we were able to make decisions and introduce modifications over short decision-making paths. Furthermore, aspects of this application made it possible to implement many new FlexRay features meaningfully.

When did you decide to eliminate CAN entirely as a fall-back solution in this project?

Peteratzinger: That was done in a relatively early phase of the project in the summer of 2004. After we had successfully started up FlexRay as a bus system to network the five ECUs in a stable manner and had all identified and assessed unresolved risk issues,

Martin Peteratzinger, Graduate Engineer (University of Applied Sciences), develops electronics in the vehicle dynamics area of the BMW Group and has functional responsibility for the FlexRay application.

VECTOR'S CANAPE

Optimization of ECU parameters with CANape

the decision was made to eliminate CAN altogether beginning with the next hardware level. In the process this raised the question: How would we calibrate the application? Initially calibration was still performed via CAN, but in the end this fall-back level was dropped. Therefore we first developed a CCP-CAN-FlexRay gateway that converts CCP messages to FlexRay and in the reverse direction too. In the ECUs we also "restructured" the CCP module for FlexRay. This made it easier to continue utilizing CANape with CCP (CAN Calibration Protocol). But that too was just a transitional solution, since first it is necessary to create such gateways, and then they need to be maintained for a number of years. Therefore it was important to find a product that would not just work exclusively in one project, but would be available to the entire market. In the ASAM working committee XCP on FlexRay was driven by Vector with the support of BMW and attained specification status in February 2006.

Schuermans: Technically we had gotten a handle on the "measurement & calibration via XCP on FlexRay" concept relatively quickly. For Vector though it was clear that we had to turn XCP on FlexRay into a standard as quickly as possible. ASAM has been working on XCP for quite a long time now. XCP itself was finalized in 2003. The aim of the standard is to only require adaptation of the underlying transport protocol. The specific solution needs at BMW allowed us to implement both the XCP stack in the ECU and on the tool side CANape as the XCP Master very quickly.

XCP on FlexRay was standardized in February. What was involved in this process?

Schuermans: Of course the work in ASAM requires a certain amount of time: First a project application is submitted, then a working committee is formed, and finally a draft is developed. XCP is split up into several subdocuments. Part 1 is an overview of the protocol family, XCP features and basic definitions. Part 2 of the document describes the XCP command set as a bus-independent protocol layer. Whenever a new Transport Layer is added, as is being done now with FlexRay, a Part 3 document is created.

What does all this discussion about dynamic bandwidth control really mean?

Schuermans: A part of the XCP on FlexRay specification defines dynamic bandwidth control. Since the XCP protocol is essentially a Master-Slave communication protocol, the XCP Master can distribute XCP Slots to individual Slaves depending on how much bandwidth the Slave needs. Dynamic bandwidth management requires that the Master knows which slots are available for this purpose. That must be a part of the FIBEX file.

Why is that good?

Steiner: Compared to the potential bandwidth of FlexRay the current bus load is still very small. We therefore had the luxury of making three XCP slots available to each ECU: One to communicate from CANape in the direction of the ECU, and two to send measurement data from the ECU in the direction of CANape. That means that 15 slots are used just for XCP. In the next car models the bus will be utilized more intensively with more ECUs. Then we will no longer have this freedom. All ECUs must then share one slot or just a few slots for XCP.

Florian Steiner, Graduate Engineer (University of Applied Sciences), develops electronics in the vehicle dynamics area of the BMW Group and as a FlexRay development expert he is responsible for production-level ECU development.

The only limitation here is that it will no longer be possible to calibrate all ECUs simultaneously. However, this is of no consequence in practice, because developers generally only calibrate their "own" ECU. With dynamic bandwidth allocation this can be done very quickly.

That is XCP will remain in the ECU?

Steiner: Yes! Although there is no need for direct measurement on the FlexRay bus while it is in service, the XCP module will be retained in production versions of the ECU. Diagnostics of the FlexRay ECUs is performed via OBD, the standard diagnostic interface in the vehicle. XCP plays a central role in testing and validating ECU functions and is therefore a component of the production software.

Doesn't that pose a risk? Certainly there are people who might want to reprogram the chassis.

Schuermans: XCP, and I am not just referring to XCP on FlexRay here, has a so-called Seed&Key security mechanism. XCP is of course based on a Master-Slave principle.

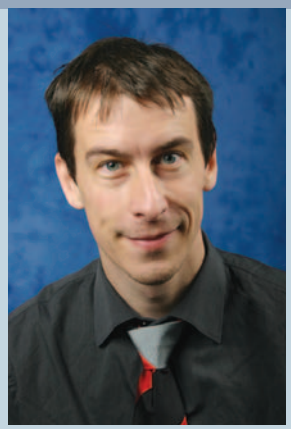
INTERVIEW

The Master must ask the Slave for a "Seed", and this is used to compute an associated key. The Master does not grant the Slave access until the correct key is obtained.

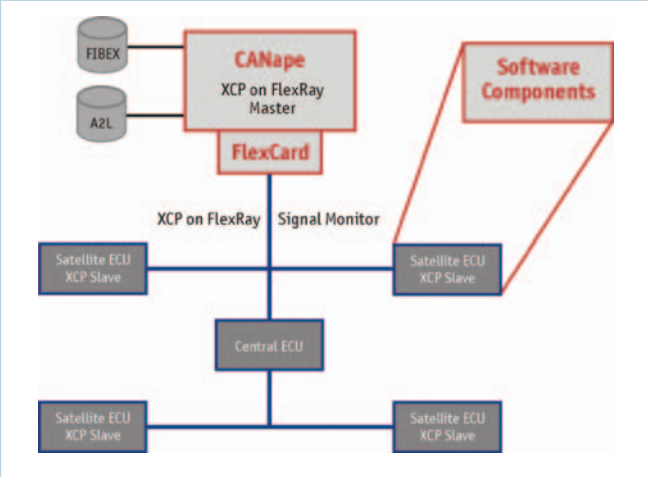
Peteratzinger: Our hardware supplier has also installed another software protection mechanism. So protection is twofold.

What did Vector bring to the table as a partner with FlexRay?

Peteratzinger: Important was this: We need to measure and calibrate signals internal to the ECU. It might have been possible to turn to other suppliers for a solution. In this context there were many open issues. During HANSER automotive's FlexRay Product Day in 2004 we met with experts from Vector, discussed these issues and formulated our requirements. Although no standard existed yet at that time, Vector showed great interest in working with us, and wanted to implement a solution for us based on XCP on FlexRay and then make it an official standard in the ASAM working committee. It was also a good fit, because Vector's CANape product was already being used in the existing BMW tool environment, and this meant that our developers already had experience with this tool.



Roel Schuermans, Graduate Engineer, is Senior Product Management Engineer at Vector Informatik for the "Measurement & Calibration" product line. As an expert in the FlexRay protocol he has been involved in the development of XCP on FlexRay in the ASAM working committee up to its standardization and worked on its implementation in CANape.



Application of suspension control system with CANape as the XCP on FlexRay Master

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Mr. Peteratzinger, in retrospect what is your assessment of this joint effort?

From our perspective the collaboration with Vector was very good. Vector handled most of the standardization work and the first implementation. So I would like to express my sincere thanks to Vector Informatik. Calibration of ECUs with CANape and the XCP Stack performed flawlessly from the start, requiring just minimal modifications.

FIRST FLEXRAY APPLICATION AT BMW

The application is an active suspension control system. Each of the four shock absorbers has a valve with dedicated electronics to control it. The valve is able to generate different damping properties, since its continuously variable aperture determines how much and how quickly shock absorber oil is pushed from the upper oil chamber to the lower one. The central control module is interconnected with the damper modules, the so-called satellites, via FlexRay. Different than in previously implemented suspension systems, while driving the vehicle the shock absorber characteristics can be independently adapted to the specific driving situation at all wheel suspensions. The satellite electronics controls excitations at the individual wheels, while the central ECU with its higher-level algorithms monitors the overall effect on the chassis, and its control system intervenes when pitching or rolling movements occur. Direct access to internal ECU parameters is necessary to tune the suspension system in driving trials and to assure system functions in system integration.

A special measurement and calibration protocol is needed for this: XCP on FlexRay. In efforts toward the standardization of XCP on FlexRay in February 2006, Vector helped to give shape to its fundamental principles on the ASAM working committee and implemented an application concept in the Vector measurement, calibration and diagnostic tool CANape. This solution provides access to all relevant ECU parameters over the FlexRay bus.

The ECUs of the suspension system transport all functional control data in the static area of the FlexRay protocol. Although XCP communication is by definition allowed in both the static and dynamic areas, BMW only utilizes the dynamic area of the FlexRay protocol for XCP. It is also used for non-time-critical network management messages and the Transport Layer mapping of FlexRay (i.e. diagnostics, coding, flashing). Due to strict time requirements of the control functions, the cycle time is 5 ms. Scheduling is not just set for the currently implemented application, it will also be applied in precisely the same form in the next planned vehicle startups at BMW.