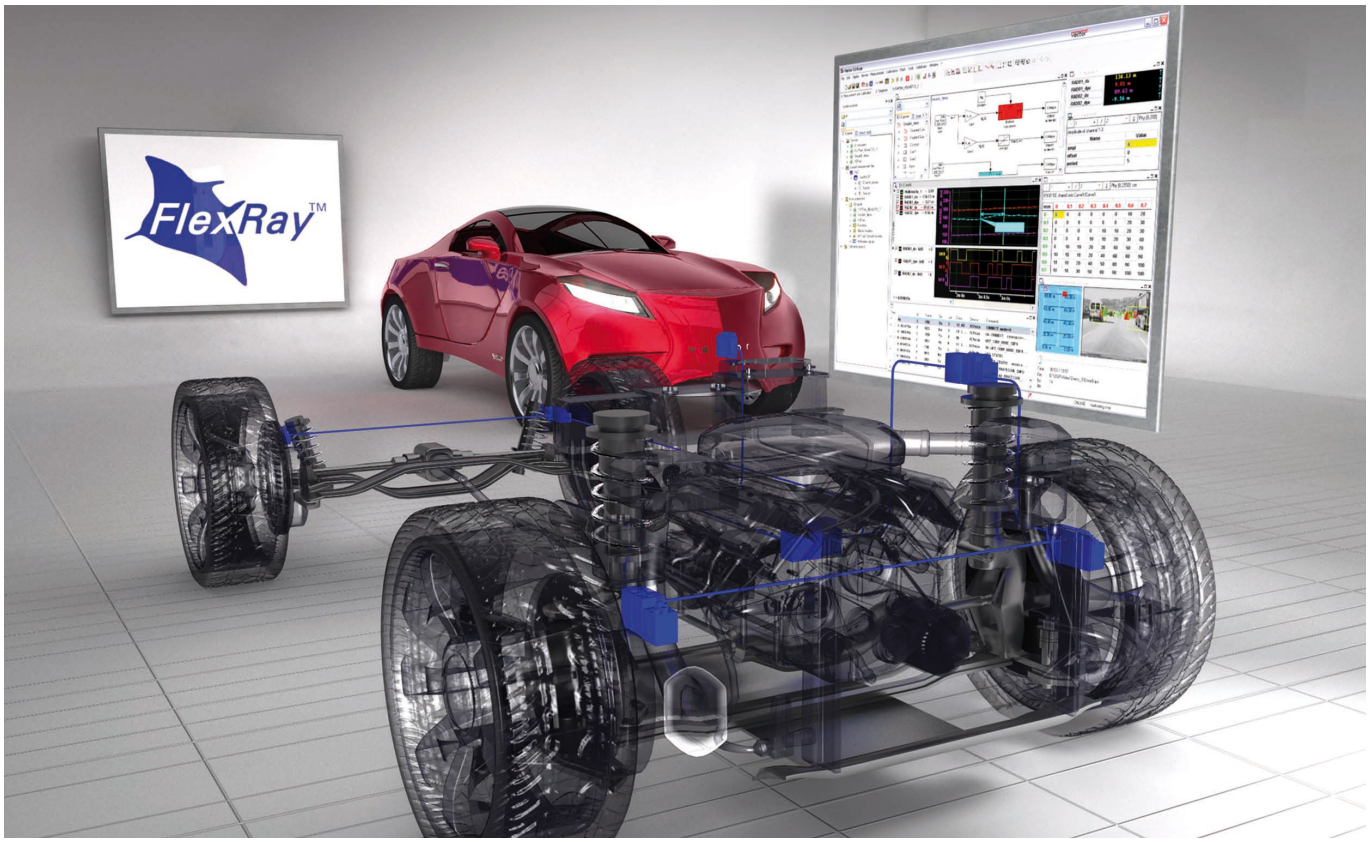
XCP-on-FlexRay at Audi

AUTOSAR-compatible XCP software modules for FlexRay ECUs



To adjust parameter values in FlexRay ECUs, Audi calibrates them via XCP-on-FlexRay. One of Audi's requirements was AUTOSAR compatibility of the XCP embedded software modules in the ECUs. For this purpose Vector modified both the XCP master and slave software so that Audi's electronic developers could perform efficient measurements and calibrations. This was possible thanks to dynamic allocation of the XCP bandwidth for FlexRay.

Starting in 2009, Audi will be implementing the FlexRay communication bus on its next generation of sporty luxury limousines. Since FlexRay – compared to CAN – offers a significantly greater bandwidth of 10 MBit/s. Many electronic chassis and driver assistance systems are connected to this deterministic and time-triggered bus system. For Audi developers, this decision meant that several thousand parameters needed to be directly parameterized via an AUTOSAR FlexRay stack. Compared to CAN, more than twice as many measured values can be acquired simultaneously using XCP-on-FlexRay. Furthermore, it is possible to transmit large quantities of data with a higher throughput.

XCP on FlexRay

A laboratory model by itself is of limited use in determining the parameters of a control algorithm. Although the algorithms of the functions are permanently stored in the ECU-specific software program, parameter values such as characteristic maps, curves and values need to be recorded and optimized in measurements made on the test bench and in driving trials. Audi engineers tune their chassis and assistance systems in the framework of ECU calibration, and they then load the parameter set files into the ECUs' application memory.

To calibrate ECUs centrally from a single master and via a uniform interface – over the entire course of development – a standardized measurement and calibration protocol is necessary. In 2003, ASAM (Association for Standardization of Automation and Measuring Systems) defined the universal measurement and calibration protocol, XCP, to serve this purpose. It is a logical advancement of CCP (CAN Calibration Protocol) [1]. Communication via XCP is executed by the Master-Slave principle. An XCP software module integrated in each ECU serves as a slave. The greatest advantage of the XCP protocol is that it offers separation of the transport and protocol layers. The protocol layer is the same on all bus systems,

regardless of whether they are CAN, FlexRay, Ethernet or SPI/SCI. In February 2006, ASAM officially released Version 1.0 of the Transport Layer specification for "XCP on FlexRay".

On earlier CAN projects, the Audi development team had already worked with XCP and CANape, the all-round tool from Vector for ECU measurement, calibration and diagnostics **(Figure 1)**. CANape has supported an XCP-on-FlexRay interface since 2005. Audi decided to source both the XCP master (CANape) and the protocol and transport layer software modules for the slaves using XCP-on-FlexRay from a single supplier.

XCP integration in the AUTOSAR model

Audi integrated the XCP software modules in the ECUs of various suppliers. Even after the ECUs calibration is over, the XCP software modules shall remain available. This makes efficient memory utilization and minimal execution time essential. In addition, the XCP software modules have to be AUTOSAR-compatible. Vector implemented this requirement on the XCP transport layer such that it is placed above the AUTOSAR communication stack (FlexRay or CAN) using the PDU router **(Figure 2)**. In the integration phase, the two XCP software modules are configured with the help of the GENy configuration tool and a network description file in FIBEX format.

Dynamic management of FlexRay bandwidth

Since AUTOSAR compatibility is required for the XCP-on-FlexRay software modules, this means that the PC-supported master must perform special tasks. During ECU calibration, the XCP master and slaves exchange FlexRay messages. These frames contain either Command Transfer Objects (CTO) with control commands or Data Transfer Objects (DTO) with measured or stimuli data. When such an XCP object is transmitted to the master **(Figure 3)**, the "XCP transport layer" transfers the data to the PDU router and thereby to the "FlexRay interface".

Because of the requirement for AUTOSAR compatibility, this transfer must be made in the form of an AUTOSAR-conformant PDU (Protocol Data Unit). Since the PDU originates from the XCP module, it is called the XCP-PDU. The FlexRay interface completes the received XCP-PDU by adding its own specific information in the form of a PCI header (Protocol Control Information), thereby forming an L-PDU (Data Link Layer PDU), which in turn is routed to the "FlexRay driver". That is how each participating software module completes data received with module-specific information, making it possible to reconstruct the data at the receiver. At the end of the chain, the FlexRay controller transmits the XCP data as a frame within a FlexRay slot (time window). Per the XCP specification these frames must exclusively contain XCP data. Therefore, in the cross-system FIBEX network description file, some slots in the FlexRay schedule are exclusively to be reserved for XCP-PDUs and cannot not be combined with PDUs issued from the application.

For the control commands (CTOs), two individual XCP slots are sufficient for all ECUs thanks to the slave-referenced node address (node address for XCP: NAX). The exact number of DTOs needed for the measured data or stimuli data depends on the specific measurement being executed and may vary widely over the course of a calibration. So the need for XCP slots also varies for each ECU.

To ensure that Audi engineers can efficiently transmit XCP data from multiple ECUs with a limited number of available XCP slots, it is necessary to dynamically allocate the available bandwidth at runtime to all participating ECUs. However, AUTOSAR does not allow reconfiguration of the "FlexRay driver" at runtime. Therefore, in the integration phase the "FlexRay drivers" are configured so that all XCP slots are allocated to all of the ECUs. At the same time, the

Figure 1:
As the XCP-on-FlexRay master, CANape measures and calibrates individual nodes directly via FlexRay

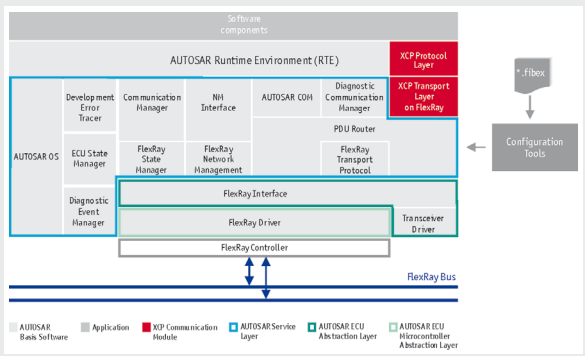


Figure 2:
Integration of Vector XCP software modules in an AUTOSAR 3.0 compatible application.

XCP-PDU/L-PDU/XCP slot allocation is set in each slave (Figure 3). As a result, at the end of the configuration process of an ECU, a unique XCP slot in the FlexRay schedule is available for each individual XCP buffer. To attain the necessary flexibility over all ECUs, the XCP transport layer command "FLX_ASSIGN" is used to modify – on the XCP level – the allocation of XCP buffers to the different L-PDUs (or FlexRay slots) before each measurement **(Figure 4)**. What is important here is to configure all participating ECUs with the maximum available XCP slots, during software integration. This results in the identical allocation of XCP slots on each ECU. Before each measurement, only those XCP buffers that are actually needed are selected. A central "dynamic bandwidth management" ensures unique ECU slot allocations for XCP among all slaves. CANape handles this task with the help of the ECU-specific A2L description files that provide information about the internal ECU buffers.

XCP use is optimized thanks to FlexRay

The new dynamic bandwidth management is only one of the FlexRay-specific CANape functions that support efficient ECU calibration at Audi. In three additional functions, Vector specifically exploits the fact that FlexRay, with it's up to 254 bytes of data payload, offers XCP frames that are many times longer than those of CAN (8 bytes). The "Short Download" function simultaneously encodes the address and contents in a single L-PDU, so that memory areas can be exchanged between the master and slave much more quickly than with CAN.

Furthermore, XCP enables oversampling, which is independent of the FlexRay cycle, in order to measure very dynamic signals **(Figure 5)**. CANape uses the so-called "In cycle multiple DAQ list transmission" to acquire measured signals of a predefined DAQ list and their time stamps multiple times per FlexRay base cycle (generally 5 ms long).

To significantly accelerate the start procedure before each measurement, the necessary initialization also had to be optimized thanks to the extension of the previous single "WRITE-DAQ" command. The new command "WRITE-DAQ-MULTIPLE" from the not yet released XCP Protocol Layer 1.1 has been already used to configure multiple signals by a single command.

Summary

Audi engineers rely on the MCD tool CANape to develop new models in the context of test trials and calibration drives, in order to measure and calibrate internal ECU parameters with XCP-on-FlexRay. Vector has extended its CANape and XCP software modules for this purpose. Besides extending the XCP software modules for AUTOSAR compatibility, a major task was to implement dynamic bandwidth management for FlexRay. Choosing Vector as software supplier and development partner was easy for Audi, since both the XCP software modules for the slaves and the XCP master, CANape, come from a single source – Vector – and are perfectly tuned to one another. All extensions can be obtained for the current version of CANape and the XCP-on-FlexRay software modules.

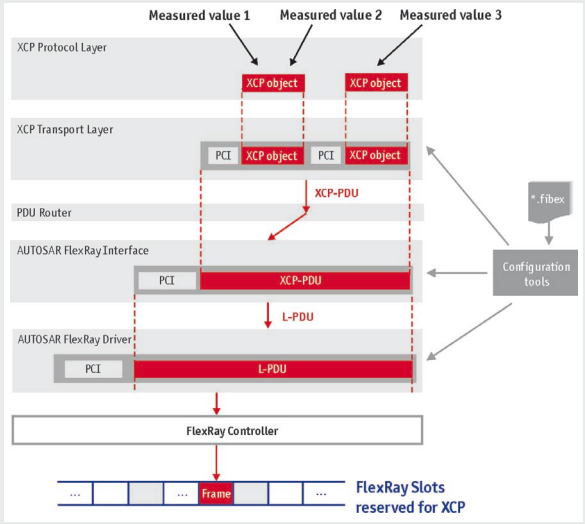


Figure 3:
XCP data are transmitted via various software modules.

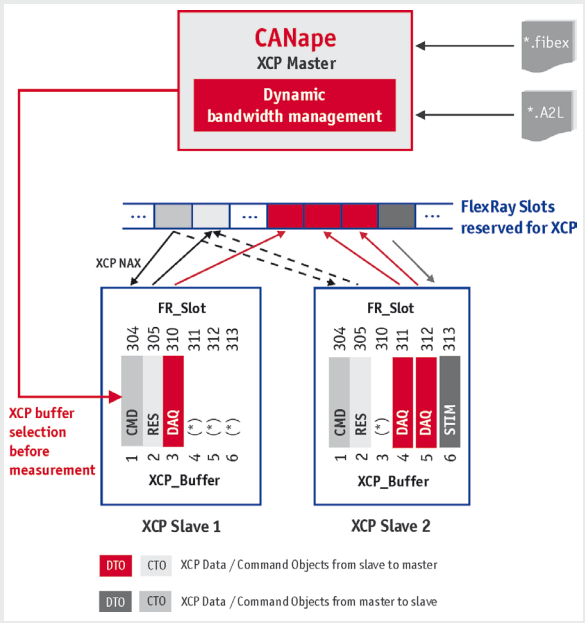


Figure 4:
Before each measurement, the XCP objects are dynamically configured in the dynamic segment.

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Literature:

[1] www.asam.net

Links:

Homepage Audi AG: www.audi.com
Homepage Vector: www.vector.com
Product Information CANape: www.vector.com/canape
Product Information XCP on FlexRay: www.vector.com/canape_flexray

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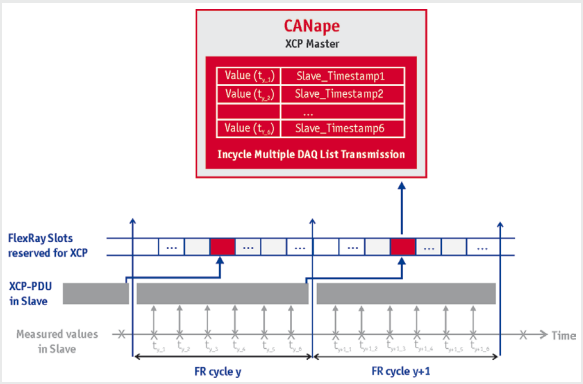

Figure 5:
The slave uses "Incycle multiple DAQ list transmission" to measure very dynamic signals from a DAQ list. The signal is measured several times per FlexRay base cycle.

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