Quantum Leap in Microcontroller Measurement Technology

Innovative ECU measurement concept for maximum data rates with minimal effects on execution time

In the development of complex ECU applications, there are greater and greater quantities of data to be processed, more signals to be measured, and a growing number of parameters to be optimized. Previous methods for measuring, calibrating and flashing are increasingly encountering limits with regard to the necessary data throughput. It was in this context that Robert Bosch GmbH initiated a search for a more powerful and future-robust measurement concept for the next generation of its ECUs, in particular for the development of a new long-range radar sensor.

The long-range radar sensor LRR3 (Long-Range Radar) from Bosch operating at 77GHz is the “sensory input“ for many safety-related and driver assistance systems. They include various versions of Predictive Safety Systems (PSS) and Adaptive Cruise Control (ACC). These smallest radar sensors in automotive industry, used in production vehicles since the beginning of 2009, are distinguished by their long acquisition range of 250m and their wide aperture angle of up to 45°. Together with a favorable price the application area is broadened from luxury class to mid-class vehicles and commercial vehicles. This development posed enormous challenges for Bosch engineers when it came to performing measurement and calibration tasks. Along with options for measuring and logging data, it was essential to have efficient methods for calibrating and flashing as well as bypassing. All of these applications require extremely high transmission rates with low latency times.

From a technical perspective, it made sense to implement a modular layout of the measurement system and to make use of a standardized PC interface. Development of a near-production ECU enabled a simple transition from development to production later on. To acquire the large number of measurement signals, up to 100,000, without errors, a data rate of at least 4 MB/s is necessary while affecting the processor as little as possible.

Existing solutions: Low data rates and high CPU load

In solutions that utilize the standardized measurement and calibration protocols [1] CCP or XCP-on-CAN, FlexRay, JTAG or SPI, a driver integrated in the ECU is responsible for periodically reading, copying and sending out the desired signal values. Due to the large volume of data to be measured, the driver requires RAM memory and processor resources that have limited availability. In addition, there is increased loading of the data bus, which impacts the ECU software in a negative way. Measurement data rates range from 50 KB/s for CAN up to maximum values of 400 KB/s for FlexRay, JTAG and SPI **(Table 1)**.

A high-performance debug interface on the microcontroller opens up new possibilities.

Bosch decided to join together with specialists at Vector to conceptualize an entirely new measurement and calibration system. As a measurement interface it utilizes the Data Trace Interface, which an increasing number of modern microprocessors are equipped with for debugging purposes. More specifically, this is a standardized Nexus Class 3 Interface, which can communicate every change in the ECU's memory to the outside world with minimal processor load.

The fundamental idea of this approach is to acquire data from the ECU via the debug interface and route it to an external measurement adapter via a special high-speed cable. The data are transmitted serially by a dedicated protocol. The external measurement adapter is able to transmit the actual measurement data to the application on the PC – independent of the ECU – via the standardized XCP-on-Ethernet protocol.

In the project, the interface on the ECU was implemented by a Plug-on-Device (POD). This POD is especially compact, and it is easy to mount it on the ECU. The POD contains all of the electronics needed to acquire and send out measurement data. To assure error-free operation, the POD fulfills the same mechanical and electronic environmental requirements as the relevant ECU. This allows the POD to be installed in critical locations in the engine compartment, for example, which was a key requirement in the development project at Bosch.

Measurement adapter with mirror memory

A HSSL (High Speed Serial Link) cable up to 5m in length connects the POD to the VX1110 base module (measurement adapter) of the modular VX1000 system developed by Vector **(Figure 1)**. The base module primarily consists of a FIFO buffer, Dual-Port RAM (DPRAM) and XCP Engine that also has dedicated RAM. Write accesses to data within the two user-definable memory areas are transferred to the FIFO buffer in the base module via the HSSL connection and the debug interface. The data are further processed and written to the DPRAM there. From a logical perspective, since this data is identical to the data stored in the ECU, the DPRAM always contains a current mapping of the data, mirroring memory areas in the ECU. The crucial aspect of this approach is that all measurement processes occur via the mirror memory. To initiate a measurement and thereby initiate data transfer, it is sufficient to have the ECU write an event number to a predefined memory address that is allocated to the measurement data. At precisely this time point, the connection between the FIFO and DPRAM is disconnected, "freezing" the memory map at the trigger time. This keeps the data to be measured constant over the measurement period. The XCP Engine now processes the data according to the protocol.

A transmission rate of up to 5 MB/s was achieved for the XCP-on-Ethernet connection between the VX1100 measurement adapter and the measurement and calibration tool on the PC. A highly robust, temperature-resistant HSSL cable was used to ensure absolutely error-free data transmission in the engine compartment. In case of transmission errors, a retransmission protocol provides for quick repetition of data packets.

A look at the system's performance demonstrates that the effort was very worthwhile. The VX1000 measurement system impresses with a measurement data rate of up to 5 MB/s, it enables a write rate of about 1 MB/s and handles the 100,000 signals of the Bosch application effortlessly. The precision of the time stamps is 1

ECU Interface	ECU Software Modification	ECU RAM Requirements	Measurement Data Rate	ECU Execution Time Effects	Bypass Latency Time
CCP/XCP on CAN	CCP/XCP driver software	1 – 2 KB	50 KB/s	Moderate	High
XCP on FlexRay	XCP driver software	2 – 16 KB	50 – 400 KB/s	Large	Moderate
XCP on JTAG/SPI	Tables for DAQ transfer via software	4 – 16 KB	200 – 400 KB/s	Large	Moderate
Data Trace VX1000	Low	None	5,000 KB/s	Very low	Low

Table 1: Comparison of different methods of measurement data acquisition.

microsecond, while bypass turnaround times of 300 microseconds were attained.

From laboratory simulations to rapid prototyping

These properties make the system ideally suited for the two primary applications at Bosch. The first application is bit-precise simulation of real scenarios in the laboratory. This involved feeding certain scenarios into the simulation without requiring real vehicle drives. The second application, bypassing, is used to execute and test functions outside of the ECU.

The described measurement system fulfills all requirements necessary for the LRR development, and it is now being used in other projects at the Bosch company. Compared to classic measurement principles, the VX1000 solution offers performance increases by a factor of 10 to 100 in all disciplines. The effect of measurements on the ECU, with CPU loading of less than 1%, lies significantly below usual values. The modular layout of the VX1000 system assures cost-effective re-use as a measurement technology solution in subsequent projects, even with different microcontrollers.

The right solution for any required measurement data rate

The VX1000 system completes Vector's product line of measurement and calibration tools at the top end of performance. Because it could reach previously unattainable measurement data rates, it fulfilled all expectations set in the Bosch project. Last but not least, along with good cooperation between the two companies, the CANape tool for measurement, calibration and diagnostics made an important contribution to successful project completion. CANape is primarily used to optimally parameterize ECUs. In the development and optimization of driver assistance systems like ACC, the CANape Option Advanced Multimedia offers specialized capabilities. Among other things, it lets users display objects detected by the system in a perspective view in time-synchronously logged video images, which gives them a reliable means for verifying object detection algorithms.

Other application options and outlook

The standardized XCP-on-Ethernet protocol can be used with both the VX1000 product line and other measurement and calibration tools. In the case of measurement and calibration tasks in the engine compartment, the VX1000 is not really an off-the-shelf product, since the harsh environmental conditions and limited installation space generally require custom modification of the ECU connection. In the framework of project work, Vector can work out individual solutions in close dialog with its customers. Devices currently supported, besides the Freescale PowerPC, are the TMS570 from Texas Instruments and the Infineon TriCore processors with DAP interface which are widely used in engine controllers **(Figure 2)**. DAP enables a cost-effective solution via a plug connector on the mini-PC-board connected to the ECU. Cycle times of 50 microseconds are possible with the measurement and calibration system. These requirements are relevant in the development of vehicles with electric/hybrid drives, for example.

Based on acceptance of the VX1000 system among automotive OEMs and suppliers, all sorts of extensions and new features will be offered in the near future. They include plans to support additional processors. Well-known semi-conductor manufacturers have approached Vector seeking recommendations on how to adapt their processor architectures in the direction of optimal measurement functionality.

Figure 1:
The VX1000 system is distinguished by very high measurement data rates and very low software modification requirements and effects on ECU execution time.

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All Figures:
Vector Informatik GmbH

Literature:

[1] XCP protocol: www.asam.net
[2] Presentations by Riedl, A. and Kless, A. at the Vector Congress 2008. Download at www.vector.com/veco08

Links:
Homepage Bosch: www.bosch.com
Homepage Vector: www.vector.com
Product Information VX1000: www.vector.com/vx1000
Product Information CANape: www.vector.com/canape

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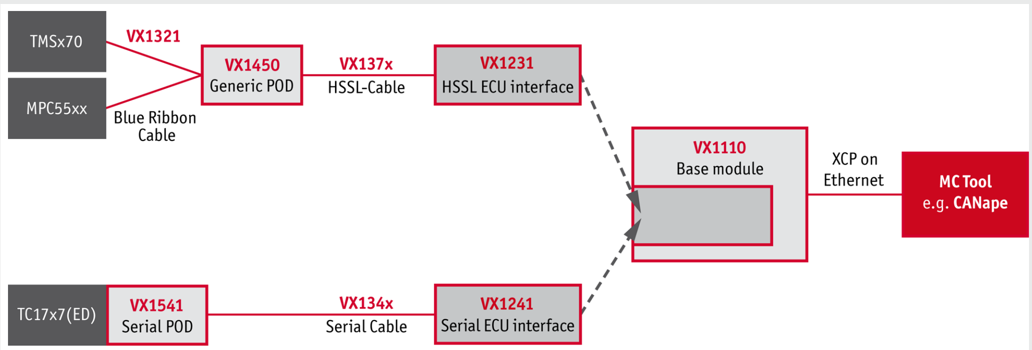

Figure 2:
High flexibility in measurement and calibration tasks is achieved by modular layout with base module, ECU interface, cables and POD.