MDG1: The New, Scalable, and Powerful ECU Platform from Bosch

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Abstract Bosch is developing an all new, scalable, and powerful platform of electronic control units (ECU) for powertrain control; launch date will be end of 2014. With this, Bosch will introduce a new powerful microcontroller generation from three different suppliers with multi-core technology which will fulfill future demands with regard to computational power. Besides this and several other innovations in hardware, Bosch will introduce a fully Autosar 4.0 compliant base software and step-by-step an Autosar 4.0 compliant application software. Our customers will have a chance to realize a seamless transition to the new ECU platform and introduce Autosar on individual timescales. Other functional enhancements will, for example, be in the field of vehicle-wide energy management. With MDG1 not only innovations in hardware and software will be introduced but in the area of processes as well. We will introduce IT standards in order to improve efficiency particularly with the integration of customer software (software sharing) and model-based development for the application software. This will bring the development efficiency—particularly for the cooperation with our customers—to a new level. With the new MDG1 Bosch will set a new standard in the market.

Keywords Electronic control units · Dual core microcontrollers · AUTOSAR · Model based development · Energy management

F2012-D03-011 Powertrain Control Unit Platform MDG1.

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SAE-China and FISITA (eds.), *Proceedings of the FISITA 2012 World Automotive Congress*, Lecture Notes in Electrical Engineering 194,
DOI: 10.1007/978-3-642-33829-8_39,

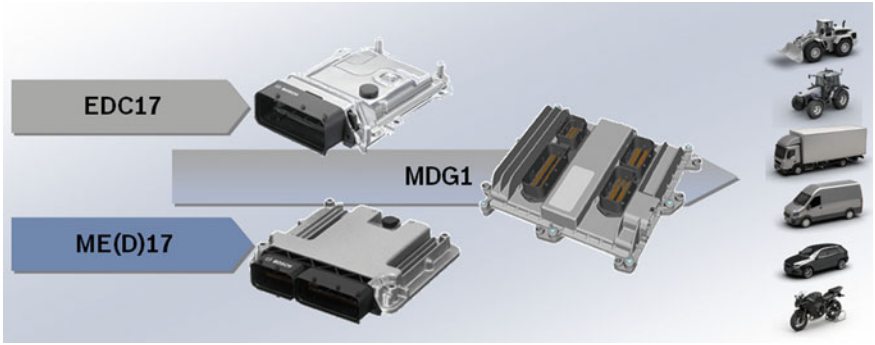

Fig. 1 MDG1 is the new scalable ECU platform for all powertrain applications. MDG1 is the unified successor of former Bosch ECU generations EDC17 for Diesel engines and ME(D)17 for gasoline engines

Bosch as not just the leading global automotive supplier but leading in the field of electronic control units (ECU) as well has business with practically all customers and in all segments around the globe. In order to support our customers also in the future, to fulfil their functional requirements and to have cost-optimized solutions available we will be introducing a new ECU platform called MDG1. With this, we will respond to the following questions: How can a new ECU platform revolutionize the powertrain control business and satisfy the OEM demand of high degree of backward compatibility to the current ECU generation at the same time? And how can an ECU platform be realized that allows a perfect functional fit and an cost-optimized solution for any powertrain application, from 1 to 12 cylinders, from 2-wheelers via all kinds of passenger cars to heavy commercial and off-highway vehicles, and from internal combustion engines to hybrid and electric vehicles? (Fig. 1).

Bosch's answer to these requirements is the all new, scalable, and powerful ECU platform MDG1.

MDG1 is the unified successor of former Bosch ECU generations EDC17 for Diesel engines and ME(D)17 for Gasoline engines. With the MDG1 platform, a nearly completely unified chipset can be used to manage Diesel or a Gasoline engines. Even the powerstage to drive solenoid injection valves could be unified by using a new programmable device.

The core novelty of the new MDG1, however, is the new microcontroller family and the corresponding software architecture.

1 MDG1 Microcontrollers

For the new MDG1 Bosch requested from its suppliers the most powerful and most scalable microcontrollers that have ever been used in powertrain applications, delivering the computational resources for today's and future innovative control functionalities.

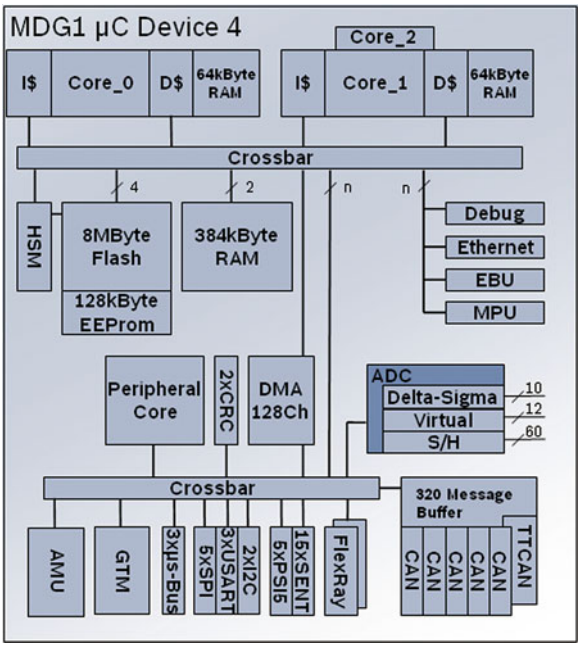

Fig. 2 Schematic description of the MDG1 microcontroller architecture on the basis of the high-end device 4

MDG1 is the first generation of Bosch powertrain electronic control units that uses microcontrollers from different suppliers which are completely interchangeable between the suppliers. This results in a multi-supplier strategy that ensures a maximum level of supply reliability. With microcontrollers in 65 and 55 nm technology from Infineon, Freescale and ST Microelectronics, Bosch is cooperating with three suppliers who reliably delivered parts for Bosch's last three successful ECU generations.

Across all three suppliers there will be 4 performance classes of microcontrollers available. Bosch calls them uniformly Device 1 to Device 4, while Device 1 is for the low-end segment and Device 4 is the high-end controller ready to support even most demanding applications. Figure 2 shows a schematic description of the Device 4 microcontroller.

Similarly to the development of CPUs in personal computers some years ago, the necessity to increase of computational power can not be fulfilled any more by increasing the clock speed only as we are hitting the technological limits regarding power dissipation and memory bandwidth. Consequently, we need to introduce multi-core microcontrollers also in embedded systems. For the MDG1, Bosch has chosen a configuration as depicted in Fig. 2 with a dual application core (Core 0, Core 1), a safety core (Core 2), and a peripheral core.

This architecture does not only have benefits for the computational power but also fulfils state of the art requirements for functional safety which becomes more and more important in automotive applications by introduction of high standards,

such as the ISO26262 standard. The safety core included in MDG1 microcontrollers (core 2 redundant to core 1 in Fig. 2) is a basic precondition for allowing building up an ISO26262-compliant ASIL-D system.

Access security has been a hot topic for automotive electronic control units for years. Illegally tempered units can cause damage and may drastically reduce the engines lifetime. In order to set a new milestone in the history of access security, MDG1 is the first ECU generation that offers a dedicated microcontroller unit called Hardware Security Module (HSM, see Fig. 2). While today's security mechanisms for tuning protection and immobilizer functionality are based on software only, the programmable HSM introduces hardware implemented security algorithms with a 2,048 bit encryption.

A special feature of all MDG1 microcontrollers is the all new General Timer Module (GTM, see Fig. 2). This module, developed by Bosch is responsible for the exact execution of time-critical operations, such as angle synchronous injection or ignition in combustion engines. The absolutely identical GTM in the silicon of all three suppliers is the basic precondition for the multi-supplier strategy of MDG1 microcontrollers.

Furthermore, in addition to well established interfaces such as CAN, FlexRay, SENT, LIN from former ECU generations, MDG1 offers innovative new interfaces such as PSI5 and Ethernet which will be integral part in future powertrain communication networks.

2 MDG1 Software

The requirements for the MDG1 software architecture are partly contradictory and exhibit a special challenge to Bosch's engineers. On one hand we want the software to be backward compatible to Bosch's previous ECU generations allowing an easy and seamless migration to MDG1. On the other hand the software shall be prepared to support future trends such as the increasingly important use of software from different sources (called software sharing), the AUTOSAR standard and functional enhancements like vehicle energy management.

Though the application software shall be as unchanged as possible, with the introduction of a new microcontroller family the hardware-near so-called base-software (BSW) needs to be adapted. Bosch decided to introduce a completely new developed BSW which is fully compliant to the AUTOSAR standard 4.0. This BSW comprises mainly the operating system, the microcontroller encapsulation and service features. One important reason for choosing the AUTOSAR 4.0 standard and not the co-existing 3.2 version is the multi-core support of the 4.0 standard. It was important for us that we do not force all customers to adapt the AUTOSAR standard in application software with the introduction of MDG1. With the help of an adapter layer (see MEDC17 adapter in Fig. 3) application software (ASW) from previous Bosch ECU generations ME(D)17 and EDC17 can be reused and combined with AUTOSAR 4.0 compliant application software modules. This allows all customers

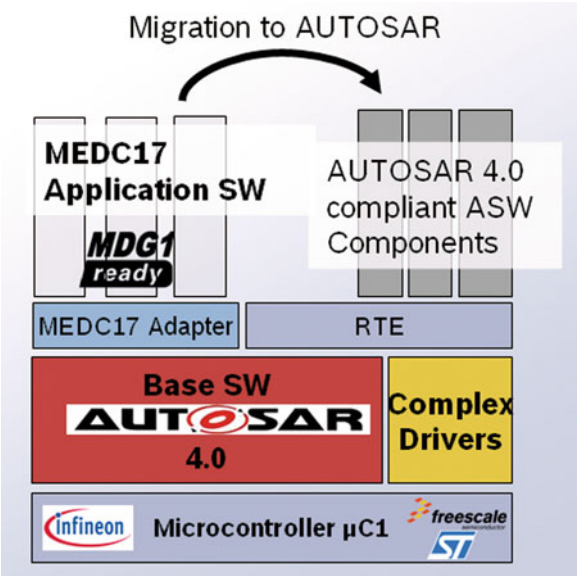

Fig. 3 MDG1 software architecture with AUTOSAR compliant base software (BSW), backward compatible application software (ASW) and microcontroller adapted complex device drivers

an individual decision if and how much AUTOSAR application software will be used and offers a smooth migration scenario. In order to make legacy software usable in the MDG1 generation it has to undergo some non-functional changes to eliminate hardware or compiler dependencies and to ensure data consistency in a multi-core environment. Without unwanted side effects like change of calibration data label names, this so-called "MDG1-ready" application software can be used in MDG1 as well as in legacy electronic control units.

Thank to the unified GTM in all microcontrollers also a single set of Complex Device Drivers (CDD) will be used in the MDG1.

3 Openness and Transparency

One of the major trends in the development of powertrain application software is the increase of software sharing between OEM, ECU supplier and sometimes even 3rd party software suppliers. The success factor for software sharing is efficient cooperation between involved development partners. Off course, Bosch has a huge experience in software sharing and is supporting this business model with many of its customers in all kinds of different ways. The intention with MDG1 is to further improve the efficiency of this process.

Despite the valid interest of each party to protect its intellectual property (IP), the interfaces and the global structure need to be openly communicated. Bosch's strategy to enhance software sharing efficiency is to provide a stable software architecture and reliable interfaces. The transparent and standardized interface

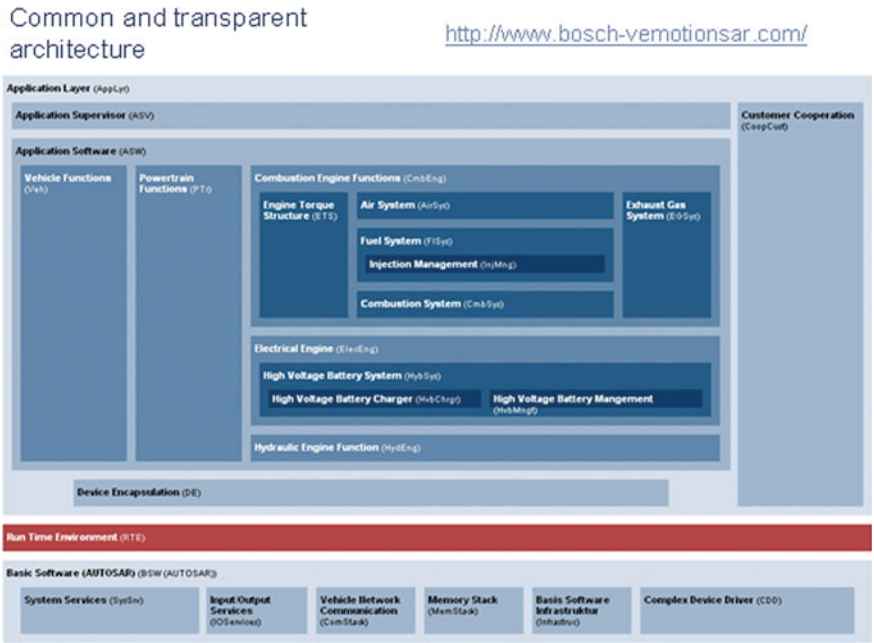

Fig. 4 The publication of Bosch software architecture VeMotionSAR™ and its interface specifications in internet in a simple and understandable way

descriptions and architecture guidelines of AUTOSAR 4.0 are the first key for successful software sharing. To gain the full efficiency benefit, Bosch is going one step beyond and publishes its own concretion of the AUTOSAR architecture for the powertrain domain, called VeMotionSAR™ (Fig. 4), free accessible for anyone in the internet (www.bosch-vemotionsar.com) in a simple and understandable way (see Fig. 4).

In addition to that, Bosch is preparing a reference implementation of the AUTOSAR Vehicle Network Communication (ComStack) and Memory Stack (MemStack) as well as main parts of the System Services (SysSW, see Fig. 4) to be available as source code for the AUTOSAR partners free of charge. Bosch will do this as an approach to reduce variability of important but usually common software parts which are not relevant for competitive differentiation. Furthermore, this will strengthen AUTOSAR as a global standard in the market.

4 Innovative Software Development Mechanisms

Software development is a fast evolving technology and development efficiency is key as the number of development engineers is limited and costs need to be contained. Therefore, we analyze continuously methods and technologies from

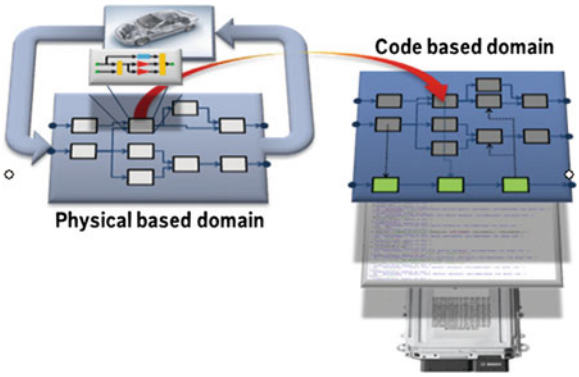

Fig. 5 Innovative software development mechanism: model-based development in close-loop system

other areas of software business regarding practicability and benefit for embedded software development.

One important method is the model based development (MBD). Graphical models already have a good representation in automotive control systems but this will increase even further. Though MBD is not new in MDG1 we are convinced that the full potential of this method is not utilized yet.

Based on the strong and open architecture of VeMotionSAR™ there will be a simplified model of the complete MDG1 application software that can easily be used for rapid prototyping of new functionalities. Easy to integrate based on the standardized interfaces new functionalities can be simulated on system level in a modeled closed-loop environment in a very early state (see Fig. 5). This allows verification, optimization and even pre-calibration of a new functionality without the effort of coding and integration and without the availability of a real ECU hardware, an engine or a vehicle. As soon as the functionality reaches a stable state it can be processed to source code in order to being integrated into a real ECU for final validation and calibration in real-life application. Integration will be a plug-and-use procedure since the interfaces in simulation and real ECU are exactly identical VeMotionSAR™ interfaces.

In combination with the support of state-of-the-art tools for modeling Matlab™/Simulink™ as well as ASCET™ MDG1 will offer various possibilities of software sharing. Depending on the preferences of our customers and development partners functionalities can be exchanged on model, source code or object code level.

With the combination of software mechanisms described above and the new powerful microcontrollers of MDG1 we will fulfill the need for efficient and cost-optimized cooperation models as well as the introduction of innovative software functionalities. These innovations include besides enhancements of internal combustion engines new electrification concepts.

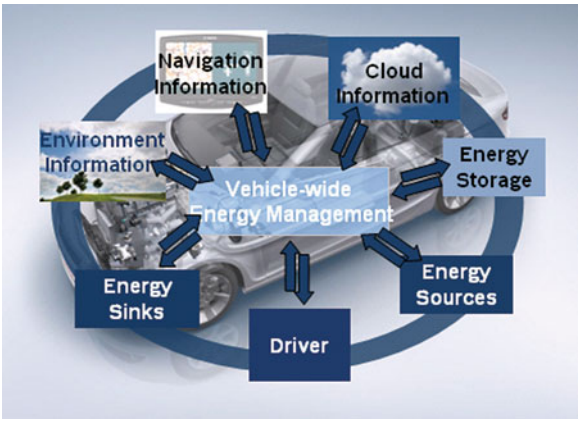

Fig. 6 Vehicle-wide energy management considers multiple information

5 Innovative Software Functionalities

Over the lifetime of the MDG1 platform, new software features will be implemented to cover future functional enhancements and customer requirements. This will include, for example, a vehicle-wide energy management with the goal to achieve an overall optimization of energy consumption on vehicle level (Fig. 6).

Since we see an increasing diversification of powertrain architectures with e.g. numerous combinations of internal combustion engines and electric motors, upcoming vehicles consist of a high number of energy sources, energy storages and energy sinks. Such a complex and flexible system can only be mastered with flexible vehicle-wide energy flow models.

And the system does not only include the vehicle itself but also its environment. With information from sensors (e.g. radar, acceleration, gradient etc., called "near-field data") as well as information from the distance (e.g. GPS, radio traffic service, internet etc., called "far-field data") situation-depending operation strategies to minimize energy consumption can be chosen. With the help of statistical analysis of driving cycles even habits of the driver can be taken into consideration in the optimization process over vehicle lifetime in the field.

6 Customer Benefit and Conclusion

With the latest, scalable microcontroller technology and the clear commitment to AUTOSAR, Bosch's new MDG1 generation offers customer-oriented and cost-optimized solutions for all future powertrain control challenges. The main customer benefits can be summarized as follows:

- Common platform for all powertrain applications, from Gasoline to Diesel and to Electrification
- Top performance and scalability in hardware and software for current and future customer requirements
- Reliability and stability of microcontroller supply
- Functional safety compliance with ISO26262 up to ASIL D if required
- Extremely high degree of backward compatibility of application software to previous ECU generations
- Customer individual, highly efficient migration to the new platform and to full AUTOSAR compliance
- Innovation in software development mechanisms to improve development efficiency
- New cooperation models with customers and more efficient project specific development and calibration
- Support of future Electronic/Electrical (E/E) architectures enabling on a vehicle level increased energy efficiency, reduction of CO2, and toxic emissions

With the new ECU generation MDG1, Bosch will define a new standard in the industry. Not only is this the most scalable ECU platform ever but it enables a smooth transition from previous generations and will bring efficiency gains in for the cooperation in software sharing. In addition, it will support the latest technology with AUTOSAR 4.0 and new software features such as vehicle energy management.

With the publication of our basic software architecture in the web we want to support all our customers in their own software development. No matter whether a customer wants to use the complete Bosch software or integrate own or third-party software modules—Bosch is the most experienced and best partner.

With the new MDG1 which will be launched end of 2014, Bosch will set a new milestone and continue with its successful ECU business.