# Development of a Scalable Multi-Controller ECU for a Smart, Safe and Efficient Battery Electric Vehicle

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**Abstract** The goal of the public funded project eFuture is to develop a safe and efficient battery electric vehicle to widen the BEV's bottleneck that is the still expensive battery, limited in capacity and lifetime. A novel E/E architecture designed to merge different the function domains HMI, ADAS, Driving Dynamics, and Energy uses a central decision unit approach based on a central control unit. An ECU developed as the core of the new architecture—yet providing carry-over functionality—is a scalable multi-controller unit with four independent 32-bit microcontroller systems. The viability of this ECU concept is successfully demonstrated on the basis of a Tata Indica Vista EV.

**Keywords** Electric vehicle · Electronic control unit

## 1 Introduction

Increasing the degree of electrification of the drivetrain, up to and including purely electric vehicles, constitutes an important part of today's efforts in greening mobility. Ultimately, the scarcity of fossile resources brings about the need to use other energy sources. Moving to electric energy both as an energy source and storage enables using sustainable sources, be it solar or water power or wind energy.

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J. Fischer-Wolfarth and G. Meyer (eds.), *Advanced Microsystems for Automotive Applications 2013*, Lecture Notes in Mobility, DOI: 10.1007/978-3-319-00476-1_18, 

Moreover, moving to a more electrified vehicle power system enables a higher degree of control of the different power flows between the individual components. Energy management on vehicle level is employed to control and prioretize the energy budget of different functions. In this regard it is obviously very important to either keep the driver closely informed, so as to ensure his compliance, or other to keep him completely unaware of possible limitations. The latter is of course limited to functions unrelated to immediate safety issues.

The work presented here is part of the research project eFuture. Started in 2010 as part of the European Commission's Green Car Initiative, its goal lies in investigating new avenues towards an efficient and safe electric vehicle [1, 2]. These new ways are being looked at from different perspectives: the user experience or the vehicle-driver interface, as mentioned above, predictive driver support through camera or navigation information, improvements in high voltage battery and drive train such as torque vectoring; however the E/E architecture offers a range of possibilities to improve on [3]. Within the frame of this paper, only a certain aspect of the different angles investigated in the course of the project will be presented, the development of a central control unit as the heart of a novel E/E architecture. As such it is housing new functions, and incorporating a new functional architecture [3, 4]. This functional architecture comprises a classical layer structure with command and execution layer. Each of the layers incorporates a so-called Decision Unit (DU). In case of the DU 1 of the command layer determines the proper prioretization and magnitude of the various control inputs, for example the driver's input, the vehicle energy management or ADAS functions, and generating the appropriate control vector. The DU 2 in turn contains algorithms which transpose the control vector into actuator actions. This operating principle is shown in Fig. 1.

From Fig. 1 another important aspect can be identified: altogether there are four levels that make up the functional architecture: the aforementioned command and execution layers, plus perception and energy layer, respectively. Within the eFuture project, the responsibilities for the different layers are split between the partners into the areas Driving Dynamics, Energy, Guiding ADAS and HMI.

## 2 ECU Realization

Based on the deliberations of the preceding section, a concept of a new electronic control unit (ECU) was developed and realized. This concept would make use of the function distribution discussed, at the same time incorporating standardization and modularization.

A key aspect lies in assigning and partitioning the computing resources. In the project presented here, four Freescale Bolero micro controllers are used. This basic aspect is clearly oriented towards the fact that within the eFuture project four partners contribute software (SW) to run on the ECU discussed here. In fact, with a function distribution onto four layers, using four controllers, and having four

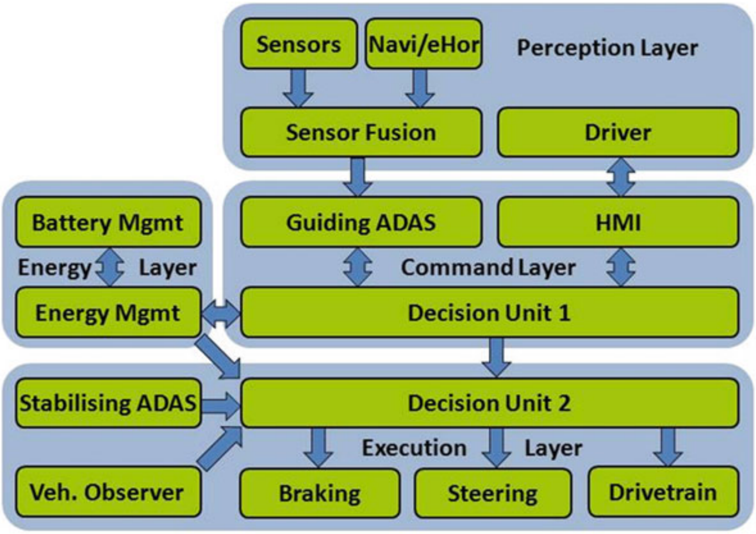


**Fig. 1** Layer-based functional architecture using a decision unit approach

partners supplying SW, it is relatively straightforward to really decouple the different software functions.

## *2.1 ECU Concept and Boundary Conditions*

As this paper details results achieved within the European project eFuture, it is necessary to outline the boundary conditions met, which of course influence the choice of concept.

Most importantly, the project demonstration vehicle is a Tata Indica Vista EV. Being an adaption of a conventionally ICE driven compact car, the base EV is further adapted. Therefore care had to be taken in order to preserve some carry over functionality contained in an ECU which was substituted by the so-called Vehicle Head Unit (VHU) presented here. An important difference between the Vista EV and the modified eFuture vehicle lies in the use of a different drivetrain, enabling torque vectoring by employing two motors, one for each front wheel. The torque vectoring algorithm runs on the VHU, and a safe and reliable communication between VHU and the motors/inverters is imperative [5, 6].

Therefore, special care was taken on designing a robust system. Robustness in turn requires efforts with regard of both hardware and software. Concerning the latter, an AUTOSAR oriented approach towards base and application software was chosen. This enables a reuse of base software for all controllers, assures a free function distribution on the application SW level, and as a result facilitates modularization and transfer to other products.

Additionally, due to the VHU substituting a conventional ECU and incorporating exterioceptive sensors such as camera or radar, a number of input/output lines and communication protocols needed to be integrated as well.

Figure 2 showcases the setup of the Vista EV, with the schematic above the dashed line depicting the conventional 12 V components, and the project specific HV related components below the line. Colour coding shows components on 12 V level in blue and HV level components in red.

## 2.2 Results

As already mentioned above, the VHU contains four mutually independent 32 bit Freescale MPC5607 micro controller systems with a system basis chip (SBC) each. This combination guarantees e.g. supply voltage regulation, and window watchdog with hardware reset generation.

These "building blocks" in turn are communicating with each other by means of a private asynchronous CAN bus.

In terms of software, the use of an AUTOSAR structure with base software layer, virtual function bus, and application layer enables a high degree of modularity on one side, and on the other side provides a well-defined method of

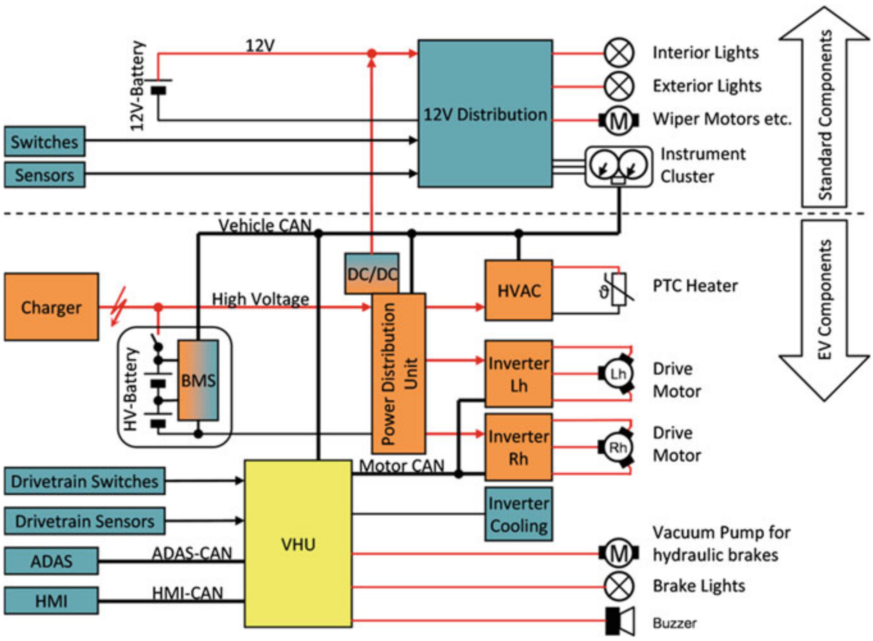


**Fig. 2** Block schematic showing the principal layout of EV components, conventional components, and the relation to eFuture's VHU control unit

communication between different application modules, i.e. functions, keeping a high degree of independence at the same time.

This unique combination served well within the project consortium, since the modularity and relative independence of the software application enabled the distribution of the individual software development efforts between the partners as well. As a consequence, responsibility for the four function levels shown in Fig. 1 is distributed too.

Using this approach an easy scalability of this method is apparent.

Another important aspect in developing this ECU was a high degree of robustness. This level could be achieved by a number of different measures:

Two micro controllers are mutually monitoring their status. In case of a detected malfunction may one controller take over duties of the other one, e.g. providing a limp home mode with limited functionality, however preventing total shutdown or even catastrophic failure. As a necessary prerequisite to this capability, important communication lines are fed to a pair of micro controllers.

As can be easily deduced from Fig. 3, this robustness is also demonstrated by the choice of connectors. Essentially, the use of two individual connectors guarantees a limited functionality even in case of one connector failing completely. Of course, the lines are not simply duplicated, however vital connections as e.g. power feed are redundant. At the same time, the wiring harness may be split in under bonnet and cabin wiring too.

Figure 4 depicts the engine compartment of the Vista EV with a mounted VHU in the centre. The vehicle was successfully integrated.

During the last project year, all software functionalities will be integrated onto the ECU. Drive tests will be performed to validate the implemented functions. Moreover the test results will be used for validating and parametrizing vehicle simulation models, as well as optimizing the control algorithm parameters underlying the various functions.

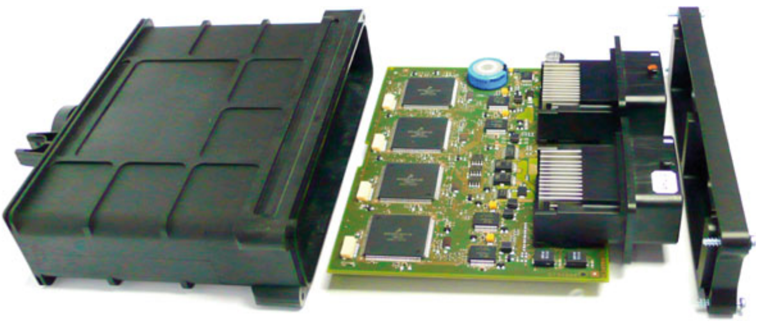

**Fig. 3** Realized VHU with outer package, connectors, and four micro controllers clearly visible

**Fig. 4** VHU in mounting position within the engine compartment

# 3 Conclusions

In this paper, a scalable ECU with a modular approach to both hardware and software was introduced. The ECU was developed within the frame of the European research project eFuture. It is part of a new E/E architecture designed to enable a safer and more efficient electric vehicle. While the vehicle has already been integrated, and base driving functionality could be successfully demonstrated, the full functionality still needs to be implemented. Validation tests are ongoing.

The authors gratefully acknowledge the financial support under the FP 7 Green Cars Initiative, grant number 258133.

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