Intelligently Controlled

Evolution of a powertrain manager for electric and hybrid-electric vehicles

____ The emergence of alternative powertrains has created new challenges for automotive engineers. The entire propulsion concept for modern cars needs to be re-engineered in order to achieve satisfying levels of efficiency and performance. Porsche Engineering considers the creation of a universal device suitable for use in any type of electric and hybrid-electric vehicles, called the Electric Vehicle Manager, and enables flexible and fast development of software architectures and functions for the powertrain of the future.

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EV manager and its architecture

The Electric Vehicle Manager (EV manager) is a highly configurable electronic control unit (ECU) that is able to form a cornerstone for any type of electric and hybrid-electric vehicles. It interacts with the driver by means of the pedals, shift lever, and ignition switch, and it controls the powertrain. It is a standard automotive ECU that typically acts on the powertrain and hybrid CAN buses, and carries out direct operation of several other sensors and actuators on its own (see illustration on page 45).

Apart from powertrain control and torque calculation, which are its main functions, the EV manager is capable of much more. Its most important functions include:

> high-voltage (HV) battery charging management,
> energy flow management,
> driving range calculation,
> cruise control,
> HMI including dashboard messages and indicators,
> brake booster control and brake blending,
> thermal management (control of the cooling systems),
> passenger compartment heating and air conditioning.

All these functions, as well as a number of others, can be added or implemented as customers wish. This high level of configurability is made possible by the unique modular structure, which allows fast customization of the EV manager for a specific powertrain and vehicle configuration by using a library of software modules. These modules can be configured and connected in Simulink, much like Lego bricks. A structure like this is used to generate the C code and automatically compile it for the specific ECU.

The modular structure of a general EV manager is shown in the illustration on page 46. The software is structured into several layers that define the level of abstraction from the vehicle hardware—these being the *core algorithms layer, vehicle mapping layer,* and *ECU mapping layer*.

The *core algorithms layer* covers functions such as torque calculation, the state machine for the powertrain, or the driving range calculation. This is the uppermost layer of the software and is largely vehicle-independent, and easy to reuse.

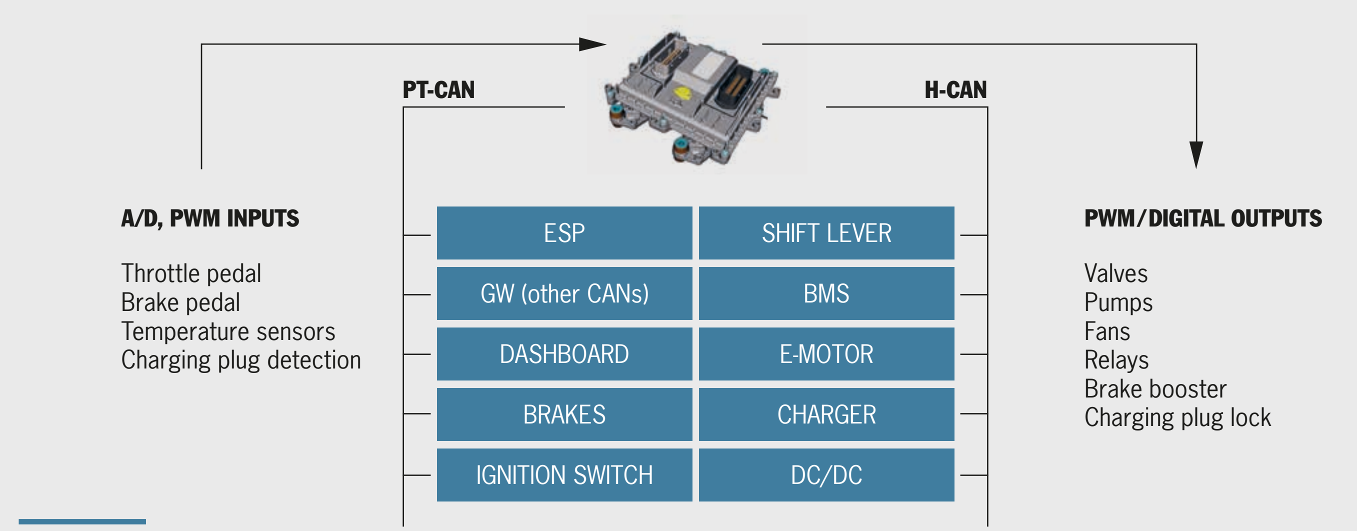
The *vehicle mapping layer* functions as an interface between the core functions and a specific vehicle platform, allowing the customer-specific functions such as thermal control, dashboard interface, HV battery charging management, or passenger compartment heating to be added. Upon replacing the battery management system (BMS) or the e-motor, for example, only a single component in this layer needs to be changed, without any changes to the rest of the software being necessary.

The *ECU mapping layer* provides an interface between the EV manager software and the lower level software used for the target ECU. This layer allows the rest of the software to be operated independently of the specific ECU. CAN messages must be parsed and converted into signals with physical units in this layer, which are processed by the higher layers of the EV manager. If a CAN matrix is available in the form of a dbc file, then this layer may be generated automatically. The EV manager can be delivered with the ECU mapping layer linked to the low level software (delivered by the ECU supplier), or alternately in the form of an AUTOSAR component with a clearly defined AUTOSAR RTE (real time interface).

A key factor enabling fast software development is the method used to define the entire architecture. All interfaces between components are stored in IBM DOORS in the form of a list of signals. This list allows standardized interface definition and is used for automatic creation of component interfaces directly in Matlab/Simulink, for automatic software documentation, and for the generation of MIL (model in the loop) test templates. All changes to the architecture are implemented exclusively in DOORS, and the rest of the process ensures their correct implementation.

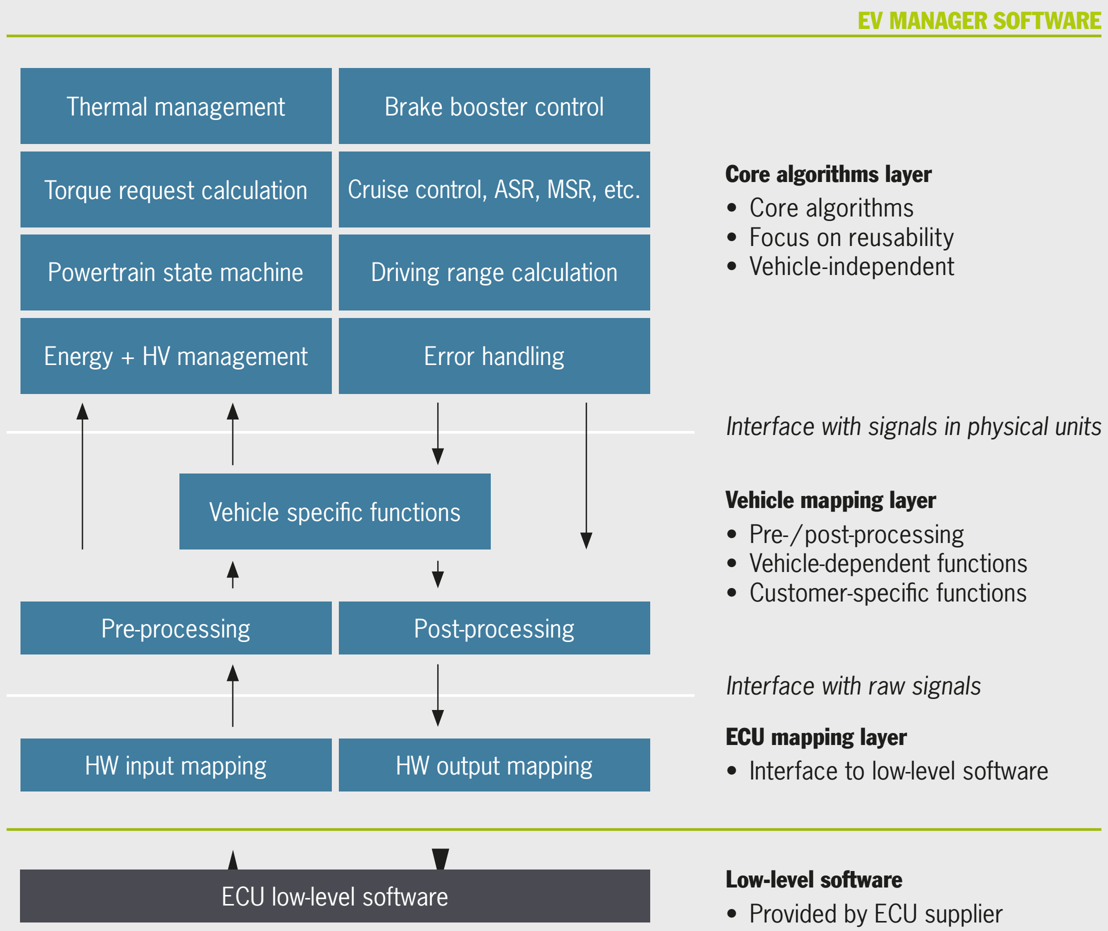
Core functions of the EV manager

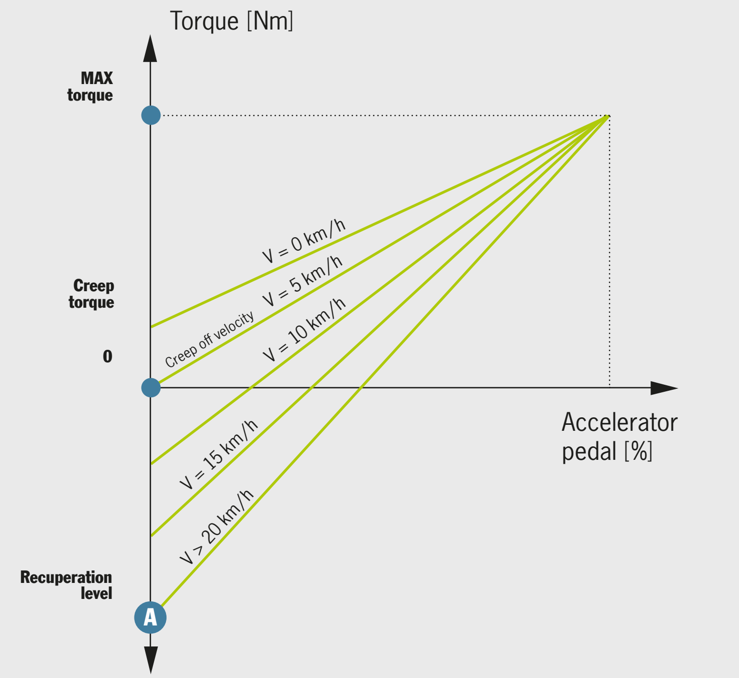
One of the most important functions of the EV manager is the calculation of the torque to be applied by the e-motor(s). To do this, the torque request calculation reads the actual position of the accelerator pedal and, depending on the current speed and other driver settings, calculates the torque it needs to apply. The torque may be positive when acceleration is required, or it may be negative, meaning that recuperation is required. ›

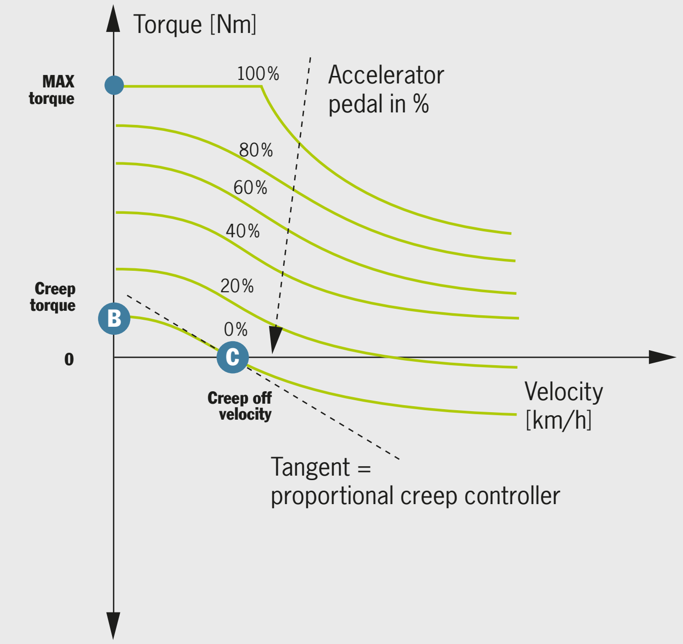


PT-CAN= Powertrain CAN
H-CAN = Hybrid CAN

Typical hardware interface of the EV manager in a vehicle—two CAN buses and several analog or digital inputs and outputs







Torque curves (accelerator pedal view)

A "recuperation level" point changes its value according to the selected recuperation level (this is usually realized using the shift lever in manual mode).
B "Creep torque" is the maximum torque value for the creep function—this torque is applied at zero velocity with the accelerator pedal released.
C "Creep off" is implemented at a specific velocity (in this setting, 5 km/h).

Torque curves (vehicle velocity view)

The tangent between the "Creep torque" and "Creep off" points explains the way the proportional creep controller functions (at lower velocities, some creep torque is required, while at higher velocities, zero torque or even recuperation is required—negative torque means recuperation).

The conditions governing the application of torque are quite complex and the customer is largely free to define the dynamic vehicle response according to requirements. For example, the complete accelerator pedal/speed/torque curves can be changed. These curves have been simplified for their depiction in the figure on page 47.

Using these curves, the customer can also define the creep controller, as it is known. The creep response, as is used in vehicles with automatic transmission, is often requested by customers. Other functions that may be calibrated and activated include the driving profiles (ECO/SPORT/SPORT+ modes), or the brake blending function. Of course, functions such as low-pass torque filtering and torque rate limiting, which help to improve the vehicle drivability, are included as well and can be calibrated in full.

Brake blending allows the driver to control the recuperation torque using the brake pedal. This function ensures that the response by the brake pedal (the braking torque) remains the same, regardless of whether it is defined by means of mechanical braking or recuperation. The braking torque is therefore blended between the e-motor and hydraulic brakes, and their respective ratio changes constantly. This function requires an electronic and an external means of controlling the brake cylinder pressure. If, for example, the brake pedal is depressed slowly, a significant share of the braking force will ultimately be generated by means of recuperation. If, on the other hand, the brake pedal is depressed suddenly and with force, recuperation is switched off and the full braking effect is generated by means of standard hydraulic braking.

Main state machine for the electric powertrain, energy and HV management

This function assumes responsibility for the overall electric powertrain state machine. The EV manager transitions between its different states, such as "ignition on/off," "drive ready," "creeping," "driving," or "charging." The state machine that is implemented in Simulink/Stateflow then ensures that the respective transition is only executed when all prerequisites are met. For example, if the charging cable is plugged in after start-up, then a transition from "ignition on" to "drive ready" will be prevented.

The energy management function ensures energy is correctly distributed among the high-voltage (HV) components (e-motor[s], battery, heating and air conditioning, DC/DC converter). The energy manager must allow for the demands from all of these subsystems, and prioritizes or reduces them respectively in the event that they cannot be fully served.

The HV manager is responsible for switching the traction battery voltage ON and OFF. The switching conditions are relatively complex and a number of safety issues must be taken into consideration. For example, the HV manager evaluates the status of the BMS, the e-motor and the driving state to prevent the HV being switched off while driving. On the other hand, it prevents the HV from being switched on in the event of problems with the e-motor or other HV equipment. ›

Driving range calculation as essential driver information

The driving range calculation encompasses a set of functions that estimate the current and average energy consumption of the vehicle (in kWh/100 km) and the driving range (in km). The algorithm is based on a moving average, while previous values are factored in with a lower priority. The time constant used for the analysis may be calibrated according to the customer's requirements. The main advantage of this method of implementation is the fact that the algorithm does not need to be reset after the vehicle has been driven a long distance.

Android-based human machine interface

Usually, the on-board computer display installed in the vehicle's instrument panel is only able to plot vehicle information on a small screen to a limited extent. An additional, high performance human machine interface (HMI) for the center console was developed to demonstrate the capabilities of the EV manager. An HMI like this allows a variety of user-defined and configurable vehicle information to be displayed on several tabs in a large, high-resolution screen. It is easy to switch between the tabs, which are fully configurable.

The Android operating system is known for its robustness and flexibility, with these advantages being the reason that this platform was chosen for the HMI. The HMI runs on a large tablet that is connected via Bluetooth to a CAN-to-Bluetooth gateway called an interface controller (referred to as IC). The IC was developed by Porsche Engineering in 2012 (see Porsche Engineering Magazine 2/2012). It is plugged directly into one of the vehicle CAN networks. The HMI is used intensively to evaluate, test and support the EV manager, as well as to increase the driver's comfort during the journey.

Commissioning and calibration

The EV manager has been successfully employed in a number of customer projects, as well as in in-house Porsche Engineering projects. The vehicle during the measurement procedure on the roller test bench can be seen on the picture below. The vehicle was commissioned and calibrated using this bench before the actual driving tests were performed.

Conclusion

The EV manager developed by Porsche Engineering constitutes a flexible and efficient solution for any kind of electric vehicle. Its modularity enables fast development of software architecture and functionalities individually tailored to the customer. ■

Measurement procedure on the roller test bench