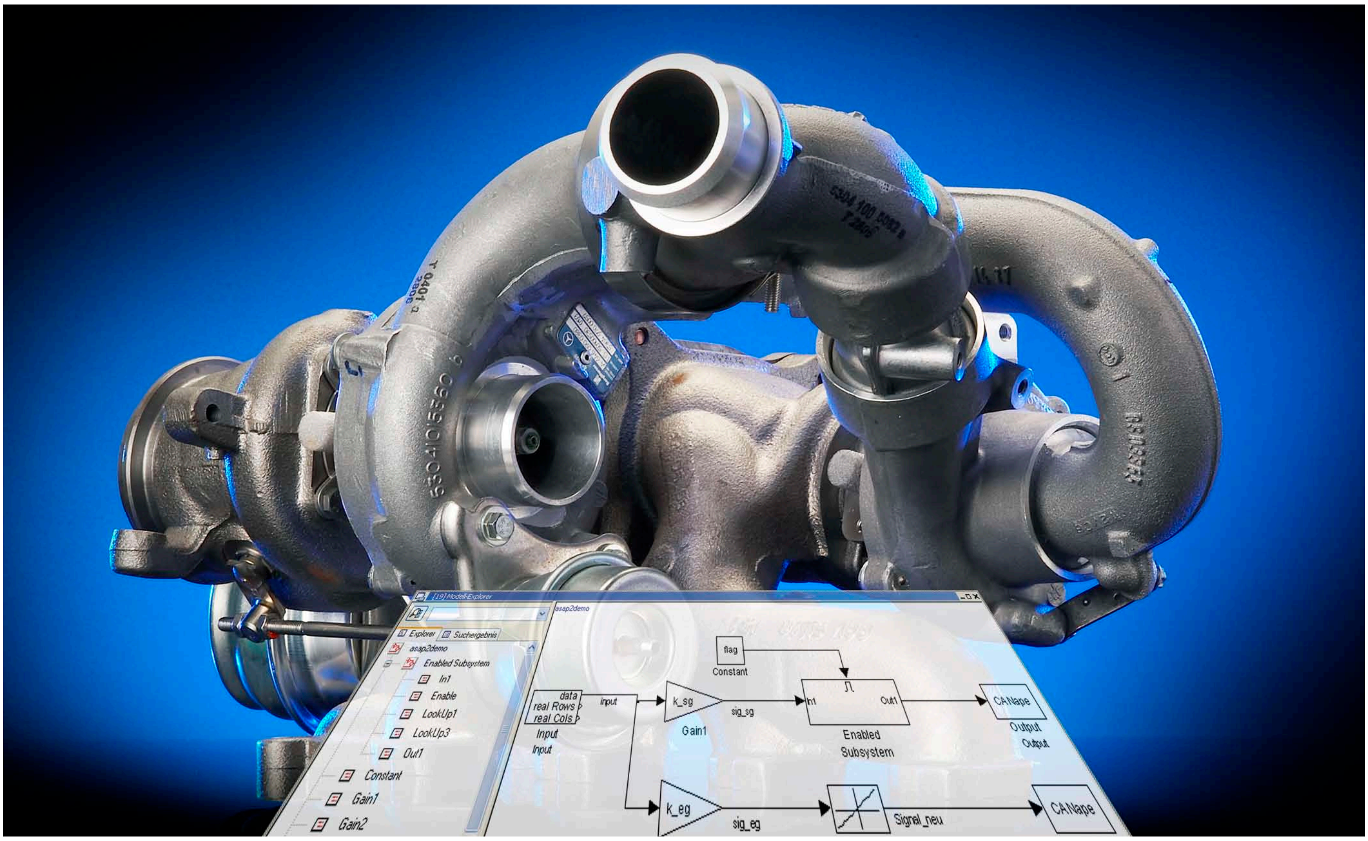
Accelerated Turbocharger Development

Efficiently developing control concepts with a cost-effective rapid prototyping solution



Turbochargers help engines, especially those with comparatively small displacements, to develop considerable torque and a high level of driving dynamics. Today's engine charging systems must flexibly adapt to engine speed and momentary power requirements; therefore, turbocharger control requires careful optimization. For the automotive supplier BorgWarner Turbo Systems, use of the CANape software tool has produced enormous streamlining potential in developing demo vehicles and hardware equipment for road durability tests.

'Charging' of combustion engines is a core technology when it comes to fulfilling requirements for low fuel consumption, low hazardous emissions and quality over long service life, while simultaneously improving driving dynamics. Today, 98% of diesel vehicles are equipped with turbochargers in the passenger car area, and on trucks approx. 80%. With the introduction of direct injection, turbocharging is also being used more frequently to improve the efficiency of gasoline engines, although the considerably higher exhaust temperatures make it essential to use higher grade materials that are more expensive.

Development competence and innovative force in demand

When a gasoline engine is driven at high power output, the turbine can become white-hot at exhaust temperatures of up to 1050°C. Simultaneously, charger speeds typically reach 220,000 rpm, and on smaller turbochargers, e.g. on the Smart car, they may even reach 300,000 rpm. Accordingly, the challenges in the development of turbochargers lie in the areas of materials engineering, cooling, bearings and high-precision manufacturing/balancing of the rotating components.

The company BorgWarner Turbo Systems with headquarters in Kirchheimbolanden, in the German state of Rheinland-Pfalz, is one of the leading producers of turbochargers; it manufactures about 3.5 million charging systems annually in Germany and about 6 million worldwide. According to company information, BorgWarner in Kirchheimbolanden currently has the most advanced development center for turbochargers in the world. Besides various standard products for diesel and gasoline engines, its product line also includes advanced developments with multi-stage control of charging systems as well as the eBooster concept.

From the 'turbo hole' to controlled charging

Due to its operating principle, high startup torque and high maximum power are mutually exclusive in simple turbocharger designs. That is, either a compact system is constructed for high charge pressure at low engine speeds or a large system optimized for high speeds is constructed that neglects the desired dynamics in the lower speed, which is then called a turbo hole.

Over the course of time, extended charging concepts have been developed to overcome this handicap, e.g. the wastegate charger equipped with bypass valve or the variable turbine geometry (VTG) that has become a standard today. Its adjustable vanes can be flexibly adapted to the exhaust gas flow. The latest developments include two-stage controlled charging with two charger systems in series and the eBooster, in which an electrically driven flow compressor supports the turbocharger.

Turbochargers increase complexity of engine control

The more refined the designs for charge pressure control, the greater the requirements for turbocharger control. In addition, it was necessary to acquire turbocharger speeds, exhaust gas backpressures and underlying parameters such as angles or positions of actuator elements by sensors and process them in the ECU. Actuators on the turbocharger consist of electrically or pneumatically actuated components for adjusting the vanes or actuating flaps and valves.

Control of the turbocharger is an integral component of engine control, and it therefore falls under the area of responsibility of the automotive OEM. In view of rising complexity, however, OEMs are relying on the support of turbocharger producers in implementing charge system control. In the development phase, BorgWarner uses the Matlab/Simulink program package to design the relevant control concepts that are provided to the customer for use on test benches or in test vehicles.

Working efficiently on the visualized model

In calibrating prototypes in the engine or vehicle, Vector`s CANape measurement, calibration and diagnostic tool performs valuable service. CANape is a powerful ASAM-conformant tool for all tasks related to ECU calibration. Via physical interfaces such as CAN, FlexRay or LIN and the standardized measurement and calibration protocols CCP (CAN Calibration Protocol) and XCP (Universal Measurement and Calibration Protocol), parameters can be measured from a PC at runtime, and they can also be calibrated at runtime. At BorgWarner the capability of visualizing the Matlab/Simulink models in CANape is particularly beneficial. Without requiring tedious searches through documentation, the user can recognize – directly from the visualized model – which parameters need to be adapted for the desired modifications. Search functions quickly lead to the desired parameters and support convenient navigation through levels of the model.

In the production vehicle, the turbocharger application is run in the engine controller. The sensor and actuator systems are also connected here. During development, the turbocharger application is swapped out to rapid prototyping hardware to enable flexible testing of different software levels. This hardware consists of evaluation boards with integrated power electronics for driving the actuators. This may involve use of an actuator/sensor combination that differs from the one in the production vehicle **(Figure 1)**.

CANape's tasks here include calibration of the engine controller and the rapid prototyping hardware as well as visualization of the Simulink model. This is precisely how CANape closes the gap between the graphic representation of the model, which lets the user visualize the interrelationships between variables, and the A2L-based calibration of the application. The parameter files created in optimization of the turbocharger application may of course be exported from CANape and read back into Matlab/Simulink. Since this layout is well-suited to both test stands and test vehicles, BorgWarner also implements it in road durability tests.

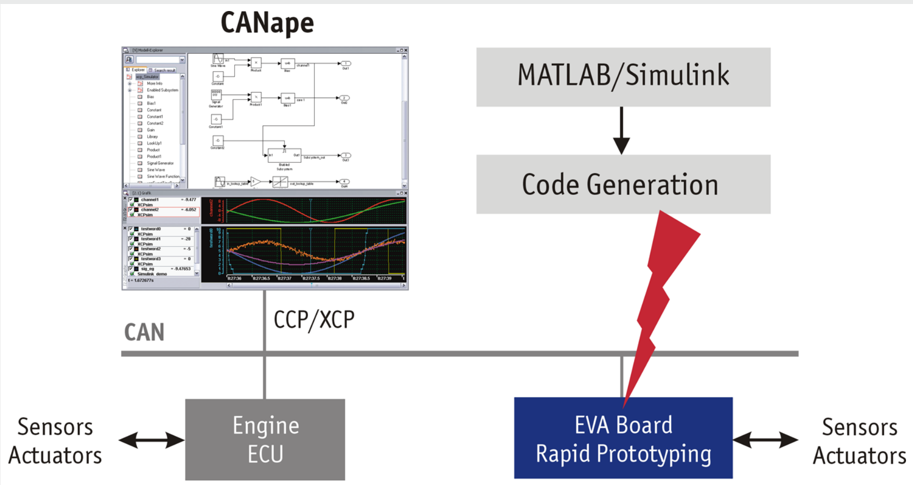


Figure 1:
CANape is used to visualize the Simulink model and serve as a measurement and calibration tool for the engine controller and rapid prototyping hardware

Outlook for the future

To achieve an even more efficient solution, BorgWarner is now testing CANape in conjunction with a PC as a rapid prototyping platform. In this case, the system makes use of a DLL generated from the Simulink model, which runs in the CANape context. The Matlab integration package supplied with CANape provides a CANape target with which the user generates CANape-specific code in the real-time workshop. The generation provides the DLL with an XCP interface, so that the user can access the DLL in measuring and calibrating as if it were running on a rapid prototyping platform **(Figure 2)**.

Together with the PC that is present anyways, CANape replaces the prototyping hardware. If the XCP protocol is used in communication with the ECU, CANape can simultaneously be used as a bypassing coordinator. The ECU data is measured in real time via the tool, is passed to the compiled DLL model of the turbocharger control system, is processed there and written back to the engine controller ECU. The big advantage of this bypassing method is that the DLL can be calibrated exactly like a real ECU. Parameter changes take effect immediately, without requiring the detour of making a modification in Simulink and then regenerating the code.

These applications point out the capabilities of high-performance development and diagnostic software in practice. CANape makes part of the hardware equipment superfluous, saves on licenses for modeling software and noticeably accelerates development progress due to fewer compiler runs. Calibration engineers at BorgWarner benefit from visualization of the Simulink model, including all of its key parameters. Even heightened real-time requirements do not pose any problem here, since bypassing cycle times as short as 2 ms are possible on PC platforms.

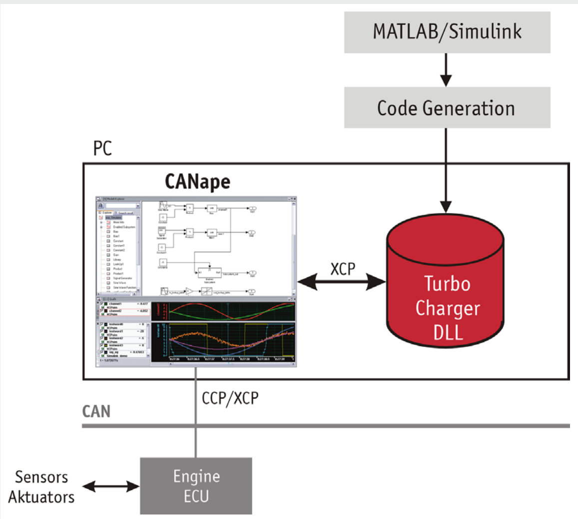


Figure 2:
PC and CANape used as rapid prototyping environment with supplemental bypassing capability.

Translation of a German publication in Hanser Automotive, 11/2007

Links:
Homepage BorgWarner Inc.: www.borgwarner.com
Product Information CANape: www.vector.com/canape

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