AVL Raptor:
Hungry for Engines

A rapid prototyping controller for combustion engines

AVL Raptor provides the customers of the entire AVL group with a quick, flexible way of creating and testing the control of complex engine configurations for demonstration and calibration purposes. The solution is based on models developed by AVL using dSPACE prototyping hardware. Models from customers and suppliers can also be included.

Rapid Prototyping for Complex Engine Controls

Engine controls help to meet a wide range of engine requirements: Current and future emission limits have to be met, fuel consumption has to be further reduced, all driving states and driving styles require optimum support – and all this has to be achieved as inexpensively as possibly. Technologies such as variable valvetrain, variable geometry turbo, and direct injection with multiple injections increase the degree of freedom, and requirements like these are what gives engine controls their high internal complexity. In the final analysis, they consist of thousands of parameters and submodels, and calibrating these takes an enormous amount of time. Calibrating the controller on a test bench can easily take up to 12 months, not including the time needed for performing in-vehicle calibration in winter and summer tests, and on the dynamometer test bench. For mass-produced engines and commercial engine controls, such a comprehensive procedure is both necessary and efficient. Performing rapid prototyping for demonstration purposes and for test operation of engine ECU software requires much faster and more flexible solutions, however. For cost efficiency, production controllers are precisely tailored to the target application, but prototyping systems for test purposes require flexible I/O, high processing power, support for managing complexity (achieved by testing subsystems or by using fewer input variables), the ability to perform offline simulation, and the ability to generate code quickly for tests with prototyping hardware.

Platform for Rapidly Developing Engine Controls

AVL has a long history of developing engine controls for production, both for OEMs and for Tier 1 manufacturers. The AVL Raptor tool set is a result of this extensive experience. The platform can be used for normal algorithm development as well as rapid prototyping. It gives the developer an environment where the functionality is tested offline using the model-in-the-loop environment, or online using the rapid prototyping controller. The simplicity with which the platform can be used offline and online really increases the pace of development, as the entire system is tested with all the interactions, not just one function with synthetic input.

AVL Raptor: Save Time Prototyping

AVL Raptor gives the international customers of AVL a complete rapid prototyping controller for test operation of engine ECU software, based on dSPACE RapidPro hardware, dSPACE MicroAutoBox, and models by AVL and models provided by customers and suppliers. Even though a production controller is often available and accessible, it is in many cases too complex or has limited I/O, so a rapid prototyping controller like AVL Raptor is an ideal solution. AVL Raptor is a complete engine controller, including a fully developed torque structure and a basic operating system, and the software is module-based, with every module in its own library. This is combined with a user interface where the user selects the modules needed for the build, making it very easy to add a component such as a new actuator or even to switch completely from a gasoline to a diesel controller. The controller uses in-cylinder pressure for closed-loop feedback control and is suitable for test bench and in-vehicle operation. It is so modifiable that it can be

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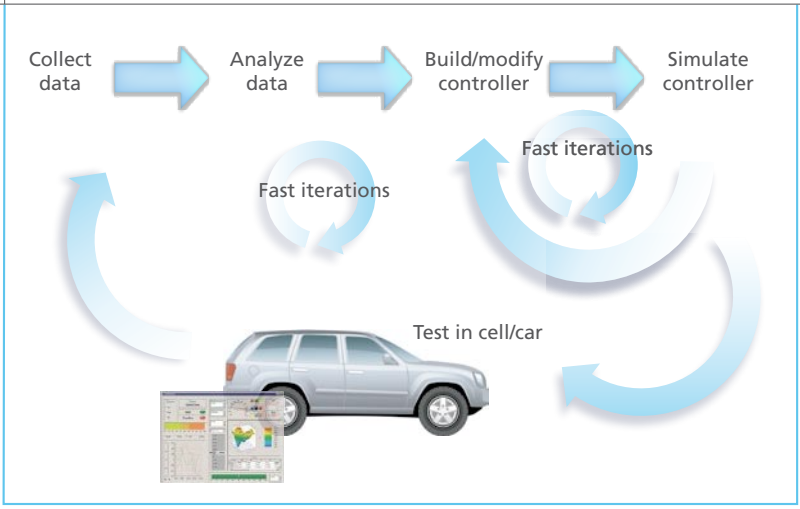


AVL Raptor: Rapid prototyping controller for offline simulation, test bench and vehicle tests.

> "The flexibility of the dSPACE RapidPro system combined with the AVL Raptor environment enables us to significantly accelerate even very complex development tasks of our customers."
>
> *Richard Backman, AVL Södertälje Powertrain Engineering AB*

Hardware and Configuration of the AVL Raptor

- MicroAutoBox
- RapidPro hardware
- Typical sensor/actuator connections (customer-specific):
  - Half bridge
  - High-pressure fuel pump
  - High-pressure injector actuator (multiple injection)
  - Injection actuator (multiple injection)
  - Support for up to 12 cylinders with additional angle-based control
  - Various crank-angle decoders
  - Camshaft phaser support
  - Lambda sensor
  - Temperature sensor
  - CAN communication using DBC files
- Complete vehicle interface
- Cylinder pressure interface

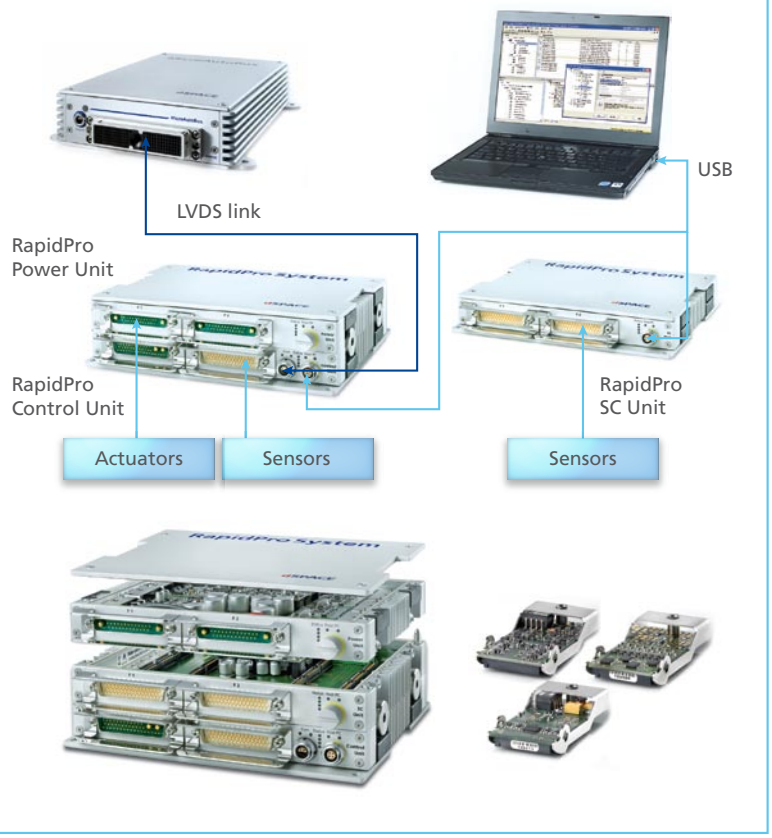
used for any engine type. With AVL Raptor, AVL and their customers can achieve 90% of the desired final state in only 10% of the time that calibration normally takes. This is ideal for demonstration purposes, for example, when new technologies are adopted.

AVL Raptor: Model Integration and Simulation

AVL provides a complete model-in-the-loop environment for running through an entire NEDC (New European Driving Cycle) offline. This environment comprises an engine model, a combustion model, a transmission model, a driver model, and a sensor and actuator model. Customers can also use other models as alternatives to those developed by AVL. The simulation time for the model and controller is faster than real time, but if there is no engine for which data can be generated to the models, AVL offers the use of advanced simulation tools, so that controller strategies can be simulated and implemented for an engine before that engine even exists. For example, it is possible to use AVL Boost for such applications. With the help of dSPACE RapidPro, the development team collects the input data and analyzes it, then builds the controller, tests it offline and compiles it, finally loading it to the real-time hardware (dSPACE MicroAutoBox). It is also possible to validate and verify production code parts on the proto-

Richard Backman
Expert, Advanced Engineering Controls & Software, AVL Södertälje Powertrain Engineering AB, Sweden

Jonas Cornelsen
Development Engineer, Advanced Engineering Controls & Software, AVL Södertälje Powertrain Engineering AB, Sweden



dSPACE hardware used for AVL Raptor.

typing hardware by means of wrapper code. For automatic tests, AVL uses the experiment software dSPACE ControlDesk in conjunction with Python scripts. AVL uses AVL Raptor in offline simulation, on a test bench, and in vehicle tests. Around 99% of all bugs in a new controller are found by simulation alone.

In Action

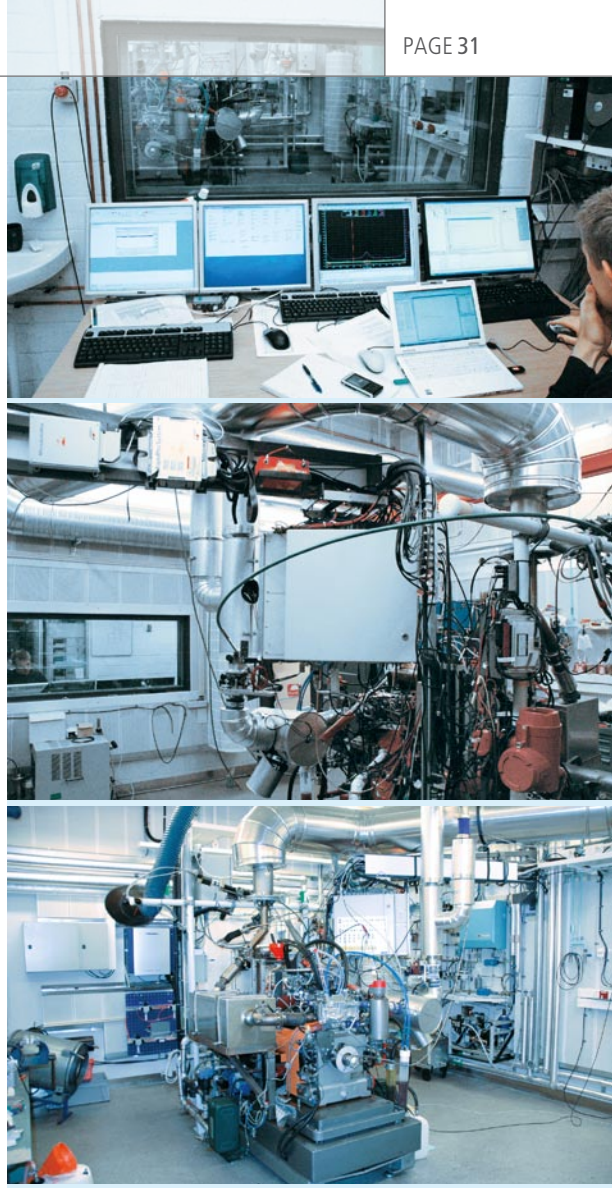
AVL Raptor is already running in numerous projects. At AVL in Södertälje, a dSPACE system controls a single-cylinder test bench for gasoline engines with a fully flexible valve system. The KTH Institute of Technology (Kungliga Tekniska Högskolan) in Stockholm is operating a comparable test bench for diesel engines, and Linköping University and Lund University are planning multicylinder test benches for gasoline engines. A demo vehicle for using AVL Raptor on the road will be available soon.

Great Application Potential

AVL Raptor enables AVL and their customers to create any conceivable, complex engine configurations, develop them in closed-loop simulation, and demonstrate them in a vehicle. This also includes technologies such as homogeneous charge compression injection (HCCI) and hybrid drives.

The rapid prototyping controller makes it possible to calibrate standard functions at a point in time when the production controller does not yet exist. AVL Raptor can also be used to run endurance tests on engines, again before the production controller even exists. AVL Raptor is especially well suited to research and teaching in the field of combustion engines. ■

Richard Backman,
Jonas Cornelsen
Advanced Engineering
Controls & Software
AVL Södertälje Powertrain Engineering AB
Sweden



AVL Raptor including a dSPACE system can control, for example, a single-cylinder test bench for gasoline engines with a fully flexible valve system.

Conclusion

- AVL Raptor: dSPACE RapidPro and dSPACE MicroAutoBox as a powerful rapid prototyping system for engine ECU software
- Flexible model integration, flexible engine configurations
- Calibration work for demonstration and test purposes dramatically reduced
- Prototyping platform for verifying production code algorithms