Riding on the Razor's Edge

Optimal parameterization of an engine controller for drag racing

In calibrating engine controllers for production vehicles, electronic developers typically work with engine test stands and numerous test drives over different route scenarios. However, no such tools are available for special engine controllers used for drag racing. Using Vector's CANape measurement and calibration tool enables an engine controller to be calibrated for top performance without using a test stand while staying within a tight budget even under the continual risk of destroying the engine after just a few test runs.

Anyone who has been to a weekend race event and seen mid-class vehicles – with production engines with hundreds of horsepower – covering a distance of a quarter mile (402.34 m) with deafening noise and incredible accelerations, is very likely watching a drag race (Figure 1). Because top engine performance is required very quickly in such acceleration races, a large share of development effort goes into calibrating the engine controller. The art of the race team's efforts is to achieve optimal results with a minimal budget. It is necessary to approach the stress limits of the engine so closely that it delivers maximum power without being destroyed. Not only the driving but also the process of calibrating the engine can best be described as "a ride on the razor's edge."

Optimally calibrated engine controller enables maximum power

In a personal endeavor, it takes a great deal of passion and enthusiasm to spend the time and money it takes to build and maintain a vehicle for drag racing. The key item here is the engine. A production engine is purchased, which is then modified by mechanical rebuilding to prepare it for the demands of racing. While the rebuild represents one side of the coin, the other involves calibrating the engine controller. All sorts of challenges must be mastered here, since the parameters of the production engine controller hardly harmonize with the modified engine any longer.

Measuring and calibrating ECUs is a challenging but daily routine in the work of carmakers and suppliers involved in production development. While calibrators run various course scenarios with the engine on the test stand and in the vehicle, they access internal parameters and ECU measurement variables via an A2L description file and find the optimal parameters. The complexity of this task significantly increases due to a whole series of constraints. On the one hand, numerous engine and vehicle variants need to be considered, and different emissions standards need to be met. At the same time, the ECU must be imprinted with an OEM-specific driving behavior. All optimizations are also subject to the premise that certain fuel economy limits must be observed. Engine calibrating is simplified by the fact that calibrators and software developers control the entire software process together. This ranges from creating the code and developing the software to the compiler/linker run, A2L generation and the flash process.

Optimal results in just a few test drives

The engine calibrating process for drag racing is fundamentally different. Neither maintaining fuel economy nor supporting different engine or vehicle variants play a role here; rather, all efforts are directed toward one goal: covering the approx. 400 meter distance as quickly as possible. Furthermore, the racing teams are not corporations with strong financial backing; rather, they are typically private individuals pursuing an expensive hobby. If faulty calibration leads to engine destruction, a lot of money needs to be spent to buy a new one.

No test stands are available for engine test runs either. For one, there are no suitable test stands due to the lack of demand for this niche application. Secondly, it is not possible to optimize the engines at their maximum speeds of up to 10,000 rpm and up to 3.5 bar charge pressure in quasi-static operation. The loads are so great that the engines could only withstand these speeds for a brief period of time (2 to 3 seconds per gear) without succumbing to heat overload.

The only feasible approach for the race teams is to acquire as many measurement variables as possible during the drive and then optimize calibration parameters based on this information. However, this approach too necessitates living with all sorts of limitations. On the one hand, the engines can only be used for a few drives before they need to be replaced. On the other, the drives usually last less than ten seconds. Therefore, the key to success or failure of the optimization process lies in finding an extraordinarily rational method.

Special engine controller replaces production device

A highly efficient engine controller for drag racing comes from the maf-map-engineering company of Berlin, Germany. This company, founded on a passion for car racing, offers a complete solution that gets maximum power out of the engines. Its capabilities are illustrated by the fastest VW Polo in the world, which trumps with 1,047 horsepower. Its performance is based on the ECU481 engine controller, whose entire hardware and software was developed by the company independently for ideal control of all components. The software is created based on physical models, whereby the Scilab modeling environment is used with an associated code generator for the functional layer. The basic software is still manually coded in C.

Since no test stand operation and only a few short test drives are possible, a primary focus is on reliable acquisition of all relevant parameters from the ECU via a cost-effective interface. That is why the standardized measurement and calibration protocol XCP

Figure 1: To optimally calibrate the engine controller, calibration parameters are adjusted in real-time during the test run based on acquired measurement results.

on Ethernet was chosen. Early on, a decision was made to search for a satisfactory professional tool which lead the team to the CANape measurement and calibration tool from Vector.

Automated parameter optimization in real-time

Key ECU parameters are calibrated by the maf-map-engineering specialists or the individual racing team; they are not calibrated after the test run, but during the test run itself – in real-time – based on acquired measurement results. Because of the extremely short test driving times it is impossible for the driver to mentally note all of the data, derive meaningful decisions from it and still send the right values to the ECU. CANape functions that enable automation of this process are especially beneficial here. Code is generated from Simulink models using the Real-Time Workshop code; after compiling and linking, it is run as a DLL in CANape. At runtime, during the test drive, the algorithm in the DLL obtains measurement data from the engine controller, uses it to compute optimal parameters and autonomously calibrates the parameters in the controller via XCP mechanisms and CANape (Figure 2).

Since the effort required to develop separate application models for all parameters would be excessive, many parameters are still adjusted manually. After the drive precise analysis of the logged measurement data with CANape reveals any critical issues and enables rapid implementation of corrections (Figure 3). In addition, the tool helps to reduce the number of necessary test drives to a minimum. New parameter values are derived from the results, which developers either set online in the controller's RAM or implement as new model values before the next code generation.

More evidence that the approach works well and is on the rise is provided by the 2010 King of Germany (KOG) event, in which a vehicle with an engine controller from maf-map-engineering took first place in the class of front-wheel drive vehicles. Meanwhile, this success in the general classification has been noted by other industries. Contacts have already been made with boat racers who are looking for a comparable solution for their race boats: an engine controller optimally calibrated for this specific field of application with efficient measurement and calibration capabilities.

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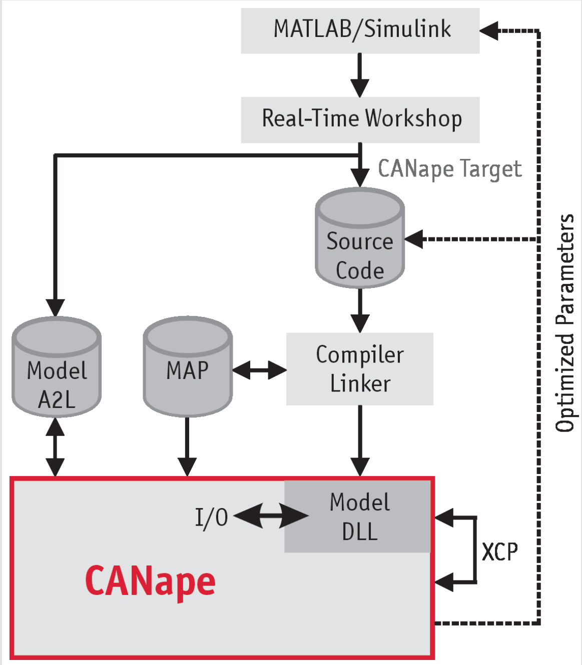

Figure 2: Besides being used to develop a control algorithm that is fed concrete data from ECUs, bus data, analog data, etc., CANape also covers other applications such as online computations during a measurement.

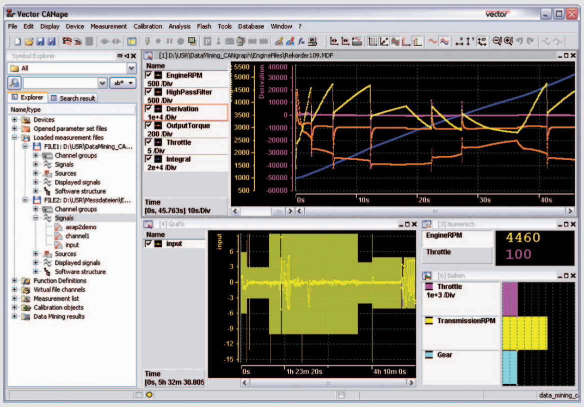

Figure 3: CANape visualizes the various parameters and offers convenient calibration options

Figures:
Lead Figure and 1: Dr. Bernd Seydel
Figure 2 and 3: Vector Informatik GmbH

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