BMW: Testing Engine Control Software

To test the software of complex engine controls, entries to the fault memory of the electronic control unit (ECU) must be prevented. In addition, almost all control loops have to be closed to allow self-diagnostics. This is only possible by means of hardware-in-the-loop simulation. So BMW uses several dSPACE Simulators to test new software. The test systems have become a vital aid to putting new engine control software into operation at BMW.

Engine Control Projects at BMW
Our department at BMW is responsible for hardware and software development in the field of engine control. We handle a diverse range of engine control projects and place great importance on close cooperation between function development and calibration teams, particularly for functions with BMW know-how such as VALVETRONIC in the BMW 3 and 7 series. In most projects, the software is developed jointly by ourselves and an ECU supplier, who provides the hardware and appropriate basic software. Our modules are then integrated into the software. BMW has always used software programming and debugging systems for troubleshooting and quality assurance. Every developer had his or her own test system for testing engine control by simulation. The tests were not complete. For example, we could not create closed control loops or adjust signals plausibly to one another, nor could we override the ECU’s monitoring functions, which protect the engine. Moreover, the systems were BMW’s own in-house developments that we supported in parallel to the software, which meant a considerable workload for us. Changing to a standardized hardware-in-the-loop system was an obvious next step.

The Change to dSPACE Simulator
We opted for dSPACE Simulator. This allows us to perform flexible engine simulations for a wide range of engine control projects and ECUs, from single-cylinder to twelve-cylinder engines. All the control loops are now closed, and operating points such as idling mode can be set stably.
The basic hardware of our dSPACE Simulators consists of a DS1005 PPC Board for model computation and two DS2210 HIL I/O Boards for generating and capturing I/O signals. The hardware is standardized and can be extended flexibly, which enables us to use several identical systems. The throttle valve and the engine immobilizer are integrated as real loads. Various cable harnesses and ECU connectors are available for different projects. This means that we can switch from one engine control project to another with relatively little effort.

Projects Run Smoothly
The setting up of the systems ran smoothly. The specification was produced by means of ECU requirement specs and the requirements of our software developers. dSPACE did all the designing, planning and assembly work. We used en-DYNA from TESIS in Munich, Germany, as the engine model. Thanks to the excellent integration properties of MATLAB®/Simulink® models, we were easily able to reuse our BMW submodels and port them to the system. New engine models were parameterized by TESIS, based on our own test bench measurements.
The software was put into operation on a production-ready ECU, and the anticipated results were verified. After this success, there was nothing to stop us duplicating the dSPACE Simulator and equipping our developers with it.

Our department has been using dSPACE Simulators since February 2002, and they have so far been used successfully in three different engine control projects. The main focus is on the following tasks:

- Verification of software at functional level, mostly without reference to complex physical conditions
- Testing of arithmetic operations
- Testing of injection and ignition timing and synchronization of crankshaft and camshaft
- Performing initial calibration
- Testing diagnostic functions

Established Position in the Development Process

It is not our intention to replace verification entirely with dSPACE Simulator. Final verification of the code and checking of the specification will always be performed on a real engine, since it is not possible to assess drivability on a simulator. However, dSPACE Simulator is a very important aid to implementing new software. Function software is particularly suitable for testing by simulator. Before new program versions are put into use, they are always checked on the simulator. For example, the engine model can be used to check ignition and injection timing “safely”.

When creating and testing the software, we partly perform initial calibration of functions, feeding data to constants and 1-D and 2-D look-up tables. In addition, by connecting the simulator to the measurement and calibration system by means of ASAP3 (ASAM-MCD 3MC), we can compare internal engine control variables and model variables. However, complete test automation is difficult to achieve, as the behavior of the engine control depends on too many input variables. Nevertheless, dSPACE Simulator provides excellent features for test automation and the reproducibility of test cases. We have since started automated testing of specific basic engine control functionalities, such as analog value capture, power-up/power-down behavior, and communication. All the tests that are performed are documented automatically for the purpose of quality assurance.

The use of simulators extends the potential for testing complex engine control software without a vehicle or engine. Many of the test steps we can now perform were very difficult or even impossible with the old systems. This considerably improves the quality of the software before it is run in the vehicle or on a test bench, meaning that verification in the vehicle is faster and more efficient. dSPACE Simulators have fast become an essential component in our development process.

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