Challenges to a Modern ECU Calibration System

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Parameterization of ECU software is a major milestone in the development process for modern powertrain and chassis ECUs. This process is known as ECU calibration. With regard to the calibration systems being used, factors such as low investment costs, investment protection and more efficient use within the overall development process are becoming key issues. The calibration tool from dSPACE GmbH provides tailored solutions for this.

1 Introduction

Modern vehicles are increasingly characterized by electronic control systems. With new legislation on exhaust gas emission, the demand for reduced fuel consumption, and rising customer expectations regarding comfort, safety and vehicle variants, the algorithms developed for electronic control units (ECUs) are growing in complexity, and the volume of software and data is increasing rapidly. Engine ECUs with up to ten thousand calibration parameters are already a reality.

Automobile and ECU manufacturers are currently employing several hundred calibration engineers and a correspondingly high number of calibration systems to cope with this task. Thus ECU calibration involves high costs for acquisition, maintenance, training and support.

At the same time, the automotive industry is experiencing stiff competition and increasing pressure on costs, so the focus is firmly on economy and investment protection.

2 Future-Proofing by Generic Components and Standards

A large number of ECUs from different manufacturers is used in modern vehicles. The ECUs can have widely divergent calibration interfaces. For economical reasons, automobile manufacturers are not interested in having a separate calibration system for each and every ECU. Instead, they aim to use just a few tools that guarantee broad coverage.

The dSPACE Calibration System therefore includes all the major calibration interfaces for powertrains and chassis (Fig. 1).

The Generic Memory Emulator (GME) provides the highest data throughput and emulation memory size [1]. The generic approach enables the memory emulator to be adapted to a wide variety of ECUs, independently of the microcontroller used. A similar approach is used for the Generic Serial Interface (GSI), which can be adapted to different on-chip communication interfaces such as NEXUS (Motorola MPC56x and MPC55xx), AUD (Hitachi SH2) and JTAG/OCDS (Infineon TriCore). Efforts currently underway in the NEXUS 5001 Forum, aimed at establishing a processor- and manufacturer-independent standard, make it likely that the GSI will be able to support further microcontrollers and system-on-chip solutions [2]. The generic design guarantees that the same hardware components can be used with different ECU versions and in different projects. The result is that the customer saves costs and the systems are easier to maintain.

Due to the variety of ECUs, another prime objective is to find calibration solutions based on standardized protocols. The Extended Calibration Protocol (XCP) is a further development of the established protocol standard CCP [3]. Strict separation of the protocol and transport layers leaves room for future in-vehicle communication standards without anyone having to modify the actual protocol. CalDesk is the calibration software from dSPACE that supports the ASAM MCD 1 standards CCP and XCP on CAN. dSPACE also provides suitable XCP drivers for ECUs. Further implementations, for example, for USB, are being planned. The dSPACE Calibration System is thus scalable with regard to performance, integration work and cost.

Compatibility with other ASAM-MCD standards is another important way of future-proofing systems. CalDesk offers systematic support of the ASAM-MCD 2 (ASAP2) and ASAM MCD 3 MC (ASAP3) standards, as well as of the Calibration Data Format (CDF). The new ASAM MCD 3 standard is also available as a COM/DCOM interface. This allows remote control of CalDesk and provides continuous measurement data capture by automation systems at a real-time rate.

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3 Using Minimum Hardware to Save Costs

In future, ECU functions will increasingly be distributed across several ECUs, and different bus systems will be used. With CalDesk, the number of ECUs that can be calibrated at the same time is not limited. Moreover, the multipage calibration concept allows page switching to be performed on all ECUs in parallel. The dSPACE Calibration System aims to impose as few system-specific hardware components on users as possible (Fig. 2). The generic calibration devices mounted in or on the ECU are therefore connected directly to the host PC via USB, with no additional devices in between. The USB interface was intentionally chosen because it is a modern technology that is very easy to handle and provides a high data rate (480 Mbit/s with USB 2.0). The USB standard also guarantees long-term availability on PCs alongside version compatibility.

The Calibration Hub from dSPACE is a simp-

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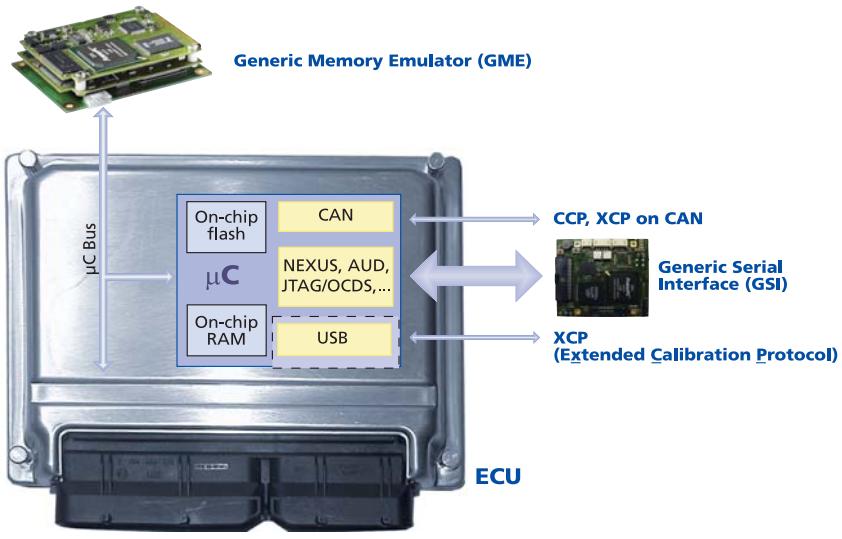

Fig 1: Calibration interfaces of the dSPACE Calibration System.

le, cost-efficient way of flexibly extending the number of interfaces. The Calibration Hub provides two USB 2.0 and two CAN interfaces as standard. There are also options for integrating further interfaces such as LIN, FireWire and Ethernet via plug-on modules. The number of channels can be increased as desired by cascading the Calibration Hubs via USB. .

ECU calibration often requires physical values such as pressure and temperature to be captured via additional measuring devices. Typically, system suppliers offer their own solutions with their calibration system. Users have to buy these devices for a specific task, so in many cases they are uneconomical to run and do not comply with in-house quality standards. The goal is therefore to continue running existing standardized and quality-assured measurement devices with the calibration system. This is particularly important in view of the need to use the same measuring devices both on the test bench and in the vehicle to achieve precise comparability of measurement results.

This is the strategy of the dSPACE Calibration System. The interface concept is intentionally an open one, allowing CAN-based measurement devices from different manufacturers to be integrated. In addition, the SIM measurement modules from IPETRONIK [4] and CANSAS measurement modules from IMC [5], both very widely used and well proven, are integrated into CalDesk at a higher quality level. The integration of the associated high-speed measurement devices with channel sampling rates of over 10 kHz via FireWire and Ethernet is also planned. The dSPACE Calibration System thus provides a calibration and measurement concept that is scalable across a wide range.

4 One Concept – From Function Design to Validation

Automobile manufacturers are now striving to implement their own function code in ECUs. The precondition for this is model-based software development aimed at verifying ECU functions in the vehicle at an early stage, starting with an executable specification and using prototyping techniques. This requires suitable calibration tools that support the entire development process seamlessly.

CalDesk provides the necessary experiment environment for the full-pass, bypass and embedded controller prototyping (ECP) approaches ([6],[7]). A new prototyping controller unit, soon to go into production at dSPACE, will be supported as well as the established dSPACE rapid prototyping platforms AutoBox and MicroAutoBox. Using communication interfaces especially optimized for each specific platform ensures a large bandwidth of measurement data capture.

Bypass technology plays a particularly important role in function development. Apart from basic features such as measurement, calibration and page switching, the dSPACE XCP on CAN driver also supports ECU bypassing and allows values to be written to the ECU consistently. Flexible configuration options make it possible to tailor the implementation of the driver with regard to functionality and resource consumption in the ECU. In addition, CalDesk and the generic calibration interfaces, which provide the highest transmission bandwidth, can be used simultaneously for bypass and calibration tasks.

As the start of production approaches, the development process focuses increasingly on vehicle testing and validation. CalDesk covers a wide range of physical measurement quantities due to the close integration of IPETRONIK and IMC modules. Special options for data analysis and post-processing are also available, so CalDesk provides a suitable solution for this phase too. As the dSPACE hardware and software components have a high degree of reusability within the development process,

3 Using Minimum Hardware to Save Costs

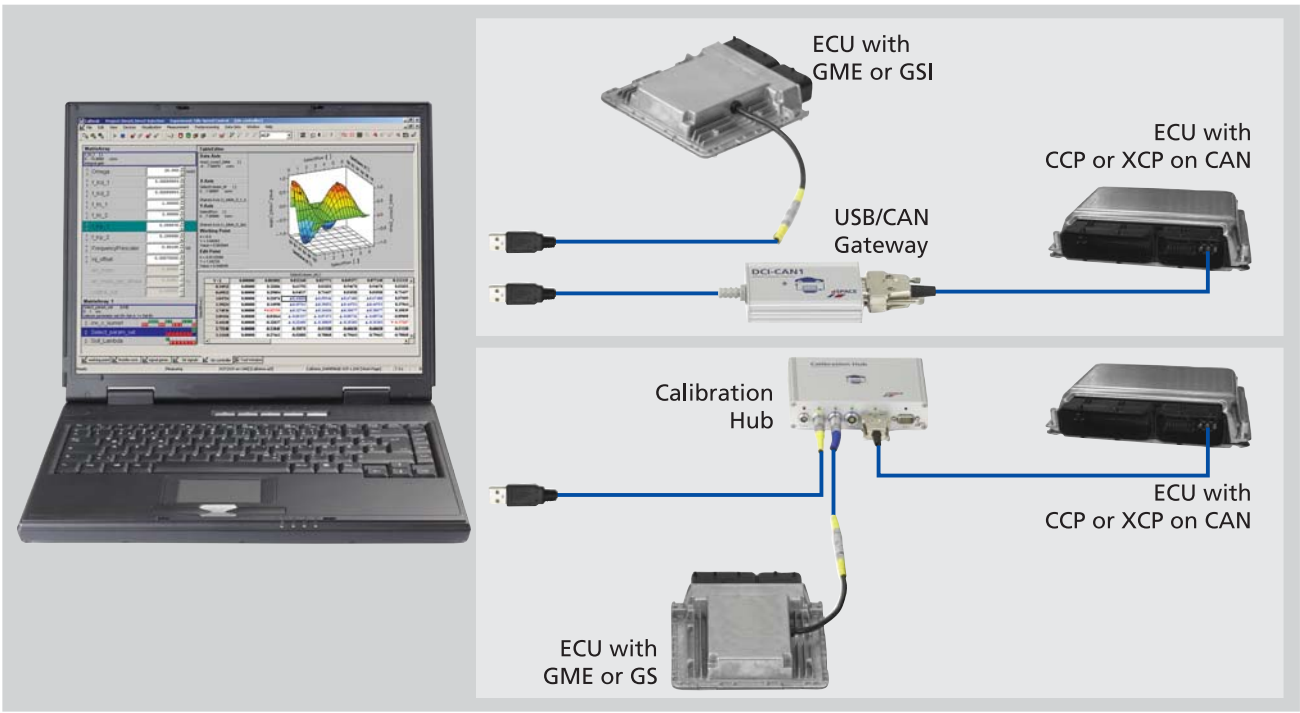

Fig. 2: Hardware concept of the dSPACE Calibration System

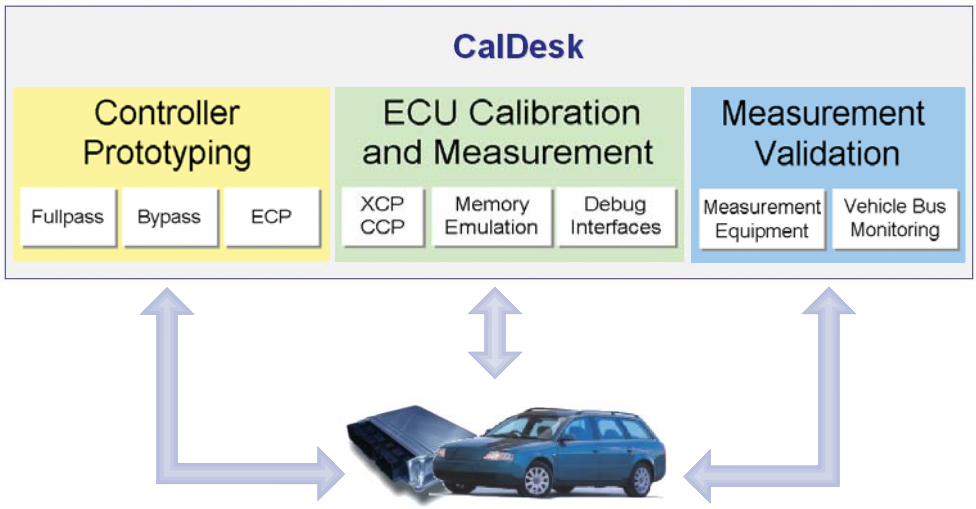

Fig. 3: Application areas of CalDesk.

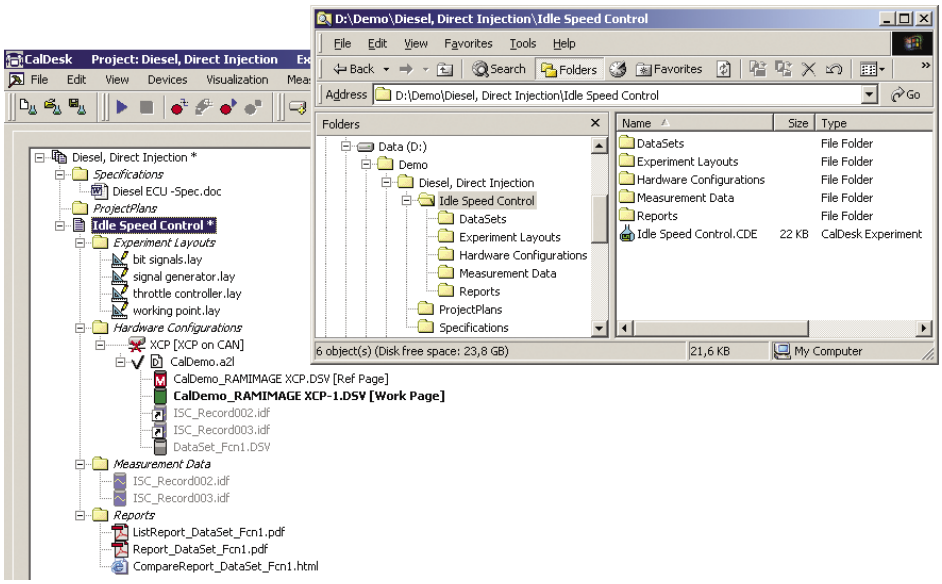

Fig. 4: Folder structure in CalDesk.

they help to reduce the expense of training and maintenance, and to cut development costs considerably (Fig. 3). Moreover, the components themselves are more widely tried and tested, and as a consequence, more mature.

5 Enhanced Acceptance Through Usability

Usability is decisive to the acceptance of calibration software. CalDesk was designed especially for calibration engineers in the automotive industry, and fulfills the following main objectives:

- Intuitive accessibility of all main functionality
- Reduction of user actions and interactions to a minimum
- User guidance to avoid misoperation

Another major goal was that the system can be operated both completely via mouse and completely via keyboard. To enable calibrators to learn how to use the software as quickly as possible, there are also options for customizing shortcut keys.

The following two examples show how these objectives are achieved:

Configurable XML templates are used to automate management tasks such as creating folder structures and assigning data sets, measurement files, and reports. During the actual calibration task, the files that are produced are automatically stored in predefined folders. This avoids unnecessary user actions and interactions. CalDesk's folder structure is identical to that on the hard disk (Fig. 4). User guidance for creating the experiment environment is provided; all

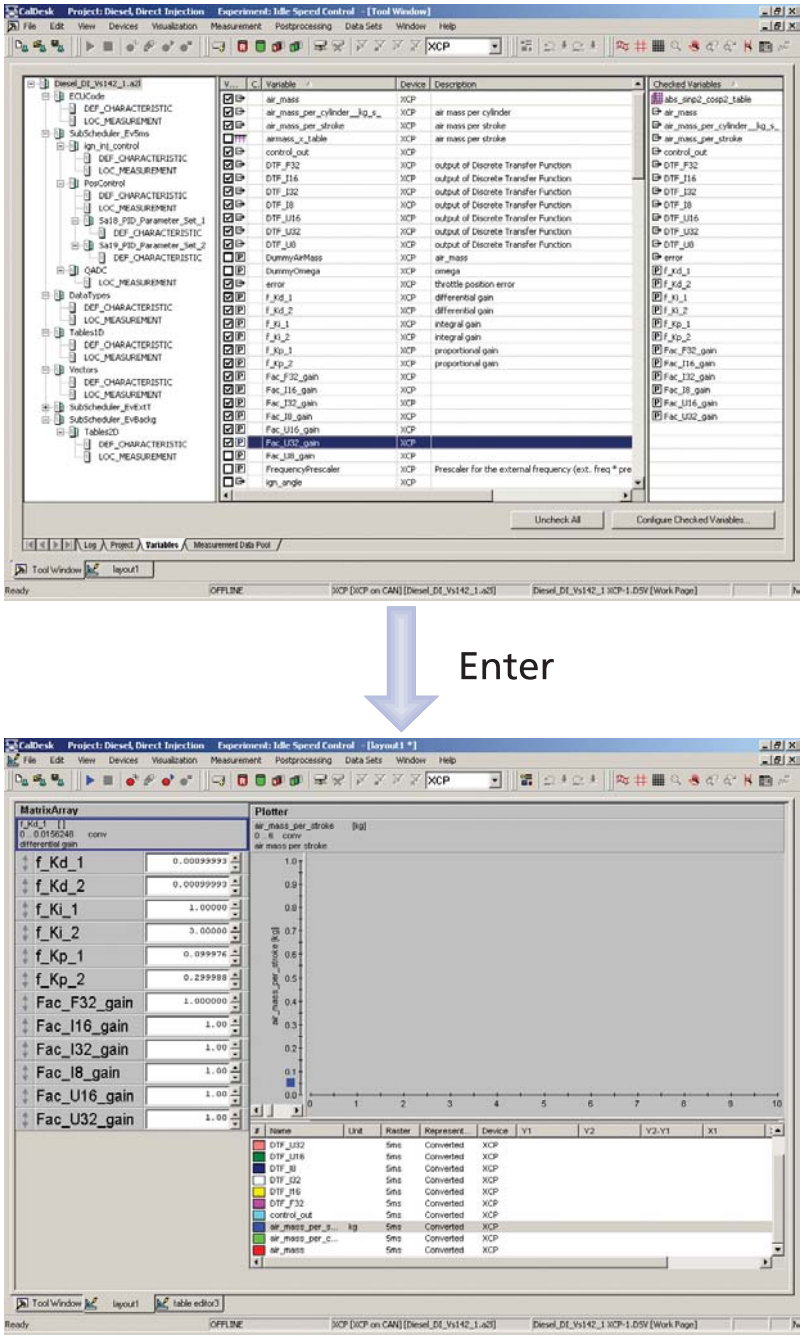

Fig. 5: Automatic instrumentation in CalDesk.

the user has to do is specify the project and experiment names, and optionally, the ECU interface and the software version.
Parameters and measurement variables that the calibrator selects in the next step can be assigned to instruments and suitably arranged on the layout automatically by CalDesk. The default instruments for parameters and measurement variables are configurable.
These examples clearly illustrate how user guidance and automation can considerably reduce the number of interactions. The result is a system that is simple and reliable to use, involving a minimum of training and support costs.

6 Summary and Outlook

The overall cost and economy of calibration systems is becoming increasingly important for automobile and ECU manufacturers. These factors are closely connected with the major issues of investment protection and future-proofing.
The uses of calibration software are no longer restricted to pure ECU calibration, but also extend to areas such as function development and vehicle testing. The dSPACE Calibration System provides suitable solutions for these tasks.
In the future, calibration systems will be more closely interlinked with modeling tools. Use cases such as feeding back parameters to the modeling environment and using the calibration software for instrumentation in offline simulations are

already being discussed. In addition, body and comfort ECUs need to be included in the calibration and validation process. This comes with closer integration of diagnostic components in the calibration system. CalDesk's software concept is ready for all of these challenges.

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